MODERN PRACTICAL BUILDING

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MODERN PRACTICAL BUILDING

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CHAPTER 1

TIMBER

TREES

THE timber used in building is cut from the forest trees ; and continuing the story of the earth's growth, it is of interest to reflect how it became possible for such immense flowering plants to root and grow on what was once a molten mass.

As explained in the chapter on Stone (Chap. 12, Vol. I) the gaseous condition of the earth was succeeded by a solidification during which certain rocks formed on the outer ring, and as further time passed, these rocks were corroded by atmospheric action, becoming broken rock and powdery in form. A mixture of various kinds of rock cemented these powders into clays, sand, and rock soil. Further gradual change produced a condition in which plant life became possible ; and for soil to be in a condition to support life it must contain " humus." Humus consists of rotted vegetable matter formed of leaves, skins, roots, etc., and how the first humus got into the soil is something of a problem, though it is possible that it came from the water, as it is a fact that certain trees are capable of absorbing humus from the water.

However, once in being, it gave life to vegetation in many forms, one of which is the tree ; and the tree is a flowering plant which grows by adding to itself yearly on the outside of its stem, which is the meaning of the term applied describing a tree as " exogenous."

The action by which the tree is nourished and grows is that the roots take in nitrogen and other dissolved mineral matters from the humus and the leaves take in carbon dioxide (CO_2) from the air. The carbon unites with the nitrogen to feed the tree, with the result that the oxygen is given out into the air again.

The root supplies are passed up the tree each year in springtime as a sticky liquid known as " sap." In a tree during its first year, this liquid passes up the centre in a tube and becomes known as the pith. This

action forms the first cellular tissue which, as the tree grows older, is the first portion to decay.

The next stage in the growth occurs in the autumn, when the sap descends the tree on the outside of the fibre formed in passing upwards during the spring. In descending, new fibre is again formed, of a denser nature than that formed during the spring, with the result that a ring, darker in colour, is formed. This process being repeated yearly, the age of the tree can be calculated by counting the darker sheaths, shown in section as rings when the tree is sawn across. During the second and subsequent years, the sap flows upwards in between the bark and the fibre last formed, and in the autumn downwards outside the newly formed fibres, forming, as has been said, another ring called the annual ring. Connecting with the bark to the interior of the tree are radiating lines of cells at right angles to the height of the tree. These are wood rays, familiarly known as the "medullary rays." Their function is to distribute food to the "*cambium*," which is the half-formed ring between the last annual ring and the inside of the bark.

The Bark is a coarser woody fibre on the outside of the tree which is added to yearly by a deposit on the inside, this interior growth producing the cracking of the outer surface in thick-barked trees such as the oak. The function of the bark is that of a skin to protect the newly formed wood. In some trees the bark is of a spongy nature, and is used as cork.

The Earlier Annual Rings gradually lose their sap and form *heartwood* or duramen. This, if the tree is felled at the right time, and before decay due to age has begun internally, forms the best wood for building. Whereas—

The Sapwood or alburnum, nearer the bark, being fuller of sap, is less suitable for constructional purposes.

Annual Rings which are wider on one side of the section of the tree than the other denote that side of the tree which faced the sun.

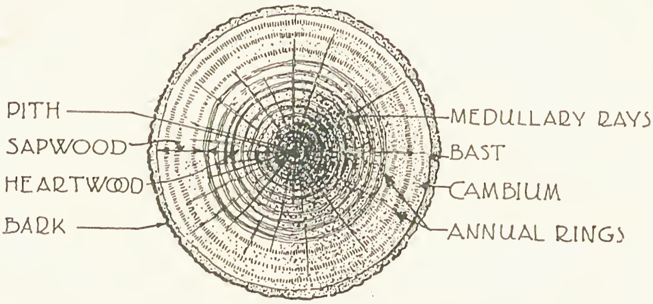


Fig. 1.—Typical section through tree.

The section of a tree when felled discloses a dried-up *pith* more or less in the centre, surrounded by concentric rings shaded from light to dark, the inner rings being *heartwood*, and the outer *sapwood*; a ring of sappy, sticky fluid between the wood proper and the bark, known as the *cambium*, and the *bark*, the interior lining of which is known as the *bast*.

If sections of wood be examined under the microscope it will be found that the wood is composed of cellular constructions, which are responsible, not only for the fibrous strength of the tree, but also for the conduct of

the internal liquids. This liquid it is that is required to be driven out by the operation known as "*seasoning.*"

So that the cycle of operations from the birth of a tree to use in a building as timber is as follows: The young tree originates from a seed either naturally deposited or sown by man. Year by year it approaches maturity by the operation explained above. It is then felled at the season of the year when there is least sap in it (winter in most temperate climates). The bark and branches are cut off and the trunk or log is left to partially season. It is then cut down its length as described later, and further seasoned in properly stacked piles. After this it is again cut into more convenient sizes, and then worked up into whatever form may be required.

Maturity.—The age at which the various trees mature and are fittest for felling varies with the variety of tree and also with the district and consequent conditions in which the tree has been grown. Consequently, the following list can only be taken as approximate.

Oak	80–100 years old.
Ash, Elm, Larch	50 years old.
Spruce, Pine	70–100 years old.
Poplar	30–50 years old.

Felling.—Opinion is divided as to the best time for felling, it being agreed that this operation should be undertaken when there is least sap present; but it is claimed by some that whilst in mid-winter the sap is at rest, in midsummer it has not thickened, and that trees felled then are more readily dried out, *i.e.* seasoned.

In this matter the Forest Products Research Special Report, No. 1, conveys the information that there is no justification for the claim that the tree contains less water in winter, and states that it may contain even more water than in the summer. Professor W. G. Craib is reported as having stated, in *Regional Spread of Moisture in the Wood of Trees*, that in certain species of hardwood trees storage of water takes place after the fall of the leaf. He found also that as the season advanced—and whilst storage, which began at the base, was still going on towards the top—an outward radial movement took place, so that by the time the tree was in full leaf, the region of maximum moisture had passed almost to the outside of the wood in the trunk, leaving the centre relatively dry. In resinous conifers this was not so, the resin in the heartwood preventing the passage.

With winter-felled timber, which is air-seasoned, there is claimed to be less likelihood of attack from wood-destroying fungi, and the trunks will dry more slowly. Timber to be kiln-dried, however, might be more suitably felled in August. Too rapid drying out of doors will cause splitting in the log from the sap drying out unequally.

SEASONING

The purpose of stacking the timber in order that it may dry out is to prevent shrinkage and cracking. It also has the effect of considerably increasing the strength even as much as 50 per cent.

As has been said, there are two seasoning operations ; the first, after the tree has been felled, and the second, after the log is cut into strips.

The logs are stacked with wedges between to enable the air to circulate all around them ; or, alternatively, they may be chained, entirely submerged in a river with the butt end upstream, and afterwards dried out.

After either of the operations is completed, the logs are cut up and seasoned in one or other of the following ways :

(1) Natural (air) seasoning.
(2) Steam heat (desiccating).
(3) Smoking over wood fires.

Natural (Air) Seasoning.—The log is sawn down its length and stacked in a manner that is known as " bulk piling."

This consists of piling the cut planks in the same order as they came from the log, but with wedges between each plank. Piling strips are laid in between each log so cut, and the whole is stacked in an open shed having a rough roof over to keep off the rain. A space is left round each stack and between each log at the sides. Thus air is enabled to circulate round and through each cut log.

The time required in Government Specifications for Air-Seasoning of the various timbers is as under :

Size.	Hardwoods.	Softwoods.
Over 24 inches square	26 months	13 months
16–20 inches	18 months	9 months
8–12 inches	10 months	5 months
4– 8 inches	6 months	3 months

Planks require roughly about half these periods.

Another method of stacking is that known as " honeycomb " piling, in which the balks are laid parallel, but with a space between of less width than the width of the balk. The next row is then laid over the spaces, each balk resting only on its edges, and so on until a triangular stack is formed. This method is not recommended for green timber, as the balks dry out faster where exposed than where touching the other timbers, with the result that shrinkage is not uniform and severe checking may be caused.

Drying by Heat in kilns or heated chambers is not considered so good a method as the natural one, especially if the temperature is too high. However, it is much quicker, requiring only about a twelfth of the time required for the natural process. The timber is stacked in racks, and heat 80–120° F. is admitted. A board or batten should be nailed across the end of each timber.

Smoke Drying is another artificial method of seasoning. This is carried

MODERN SEASONING OF TIMBER. METHOD OF STACKING.

on over wood fires, it being claimed that as the sap is driven out of the fibres the CO_2 enters and hardens and preserves the timber.

This matter of seasoning, it is pointed out in the Report referred to, is rather a more difficult one than it may appear, not in performance, but in the after results. For instance, it sometimes happens that manufactured articles fall to pieces by shrinkage after manufacture and delivery, when it is claimed that the wood must have been improperly seasoned. This is the more likely to happen to articles exported to countries having climates different from those obtaining in the country of origin, as such a result is caused by the atmospheric conditions in the two countries being different. For the condition of timber which it is customary to describe as " thoroughly seasoned " is, after all, a relative term. The operation is primarily to drive out the water from the fibres of the timber, and also to render it in a condition in which it will not readily absorb further moisture from the air. Consequently, as the conditions of humidity of the air vary from day to day, and with different conditions, such as obtain in heated houses and warmer and drier countries, it will be seen that the collapse of the articles may not be due to any fault in seasoning.

The solution of this problem would seem to lie in the adoption of a satisfactory preservative which will seal the pores in the wood equally all over. It should be noted, in this respect, that paint and varnish are not waterproof, they are only resistant ; and to paint an article on one side only is not a satisfactory method of overcoming swelling or shrinkage due to change of atmospheric conditions.

The shrinkage in timbers after they are cut from the log occur mostly in the direction of the circumference rather than from the centre towards the circumference. An approximate figure for this circumferential shrinkage is 5 per cent. reduction in the length. Consequently, a log cut down its length into thick timbers will result in a greater shrinkage being evident at the ends of the centre logs than at the centre of the same logs. The shrinkage of the outside slabs will be most marked on the outside faces, which will be likely to cause these slabs to curve outwards away from the centre of the log, on account of the greater shrinkage of the fibres on the outer faces than on the inner, with the result that there is set up a pull on the ends of the timbers away from the centre of the log.

CONVERSION OF TIMBER

This is the term given to the operation of sawing a log into timber of sizes required and convenient for use ; and whilst the most economic method is that known as

Slabbing, this method, for the reason given above, is the most likely to result in timber that is twisted. There is least waste in this method, as even the outside slabs can be used in work of a rustic nature. The inner timber will have most

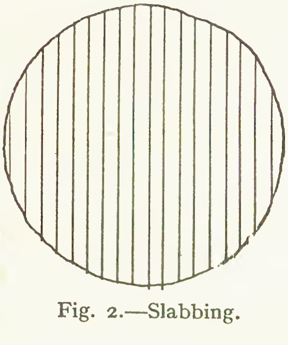


Fig. 2.—Slabbing.

heartwood, and will, consequently, be most useful in construction, whilst the outer timber will contain the most sap. Timbers so cut are stronger and more suitable for use as heavy beams.

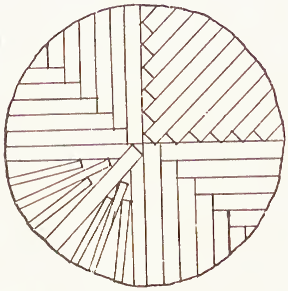


Fig. 3.—Radial sawing.

Radial Sawing is adopted for the harder woods, especially oak, as it exposes the "flower" or face of the grain. Beams so cut are not so strong as those cut by the first method, and radial sawing is less economical. The logs are cut, in this method, into quarters down their length, and then the quarters are cut down their length in one or other of the three following ways:

1. The most expensive and wasteful method, but the best if the wood is to be used for decorative purposes, is to cut the quarters down lines following the medullary rays and converging towards the centre of the log. From such a method it is to be seen that there will result from between each plank a triangular-shaped piece of timber for which uses may be found such as cutting into posts, studs, etc., but which, for the purpose of decorative work, will be practically useless.

2. A less expensive method, but at the same time less productive of "flower," is to cut the log into boards at right angles to each other; that is to say, to cut slabs off the rectangular face of the quarter log alternatively. This is the least wasteful method of radial sawing.

3. The third method of radial sawing is to cut the quarter into slabs at right angles to the chord of which the quarter circumference is the arc.

Tangential Sawing.—When woods which have no pronounced medullary rays, such as mahogany, are required for decorative work, they are cut from the log by a method of sawing known as "*tangential.*" This method consists of first cutting the log down its length into quarters, and then cutting each quarter down its length in a direction at right angles to a radius at the centre of each quarter or segment of the original log. The reason for adopting this method is that in certain woods used for decoration, the outer annual rings are lighter than the inner, and a contrast or shading is then obtained. With mahogany, though there is little difference between the colouring of the inner and outer rings, there will be a difference of texture due to the growth.

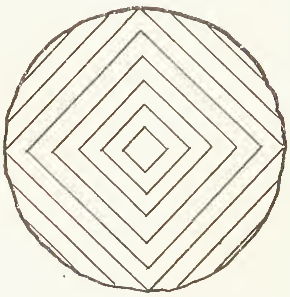


Fig. 4.—Tangential sawing.

Whilst dealing with this point, it is of interest to note that the cross sections of any timber of the same tree will vary considerably in accordance with the rate of growth. Thus a slow-grown conifer, such as Scots pine, is stronger than a quick-grown, and the annual rings are naturally closer together in the first than in the second. The greater strength here is due to the greater proportion of the dense autumn-formed wood in the

outer portion of the annual ring. On the other hand, in a more porous timber such as ash, the quick-grown is the stronger, though its annual rings are wider apart than in the slow-grown variety. The reason for this greater strength is that in proportion there is a greater amount of dense autumn wood per square inch in the quick-grown than in the slow-grown.

In this matter, and for a proper understanding of this subject, the student is recommended to increase his interest by visiting the Natural History Museum in London and the Forests Products Research Station at Princes Risborough in Buckinghamshire, where the various magnified sections of timbers are to be seen, and much is to be learned therefrom. For instance, it will be noted that wood is composed of fibre and cellular spaces between, and that whilst these spaces or channels may be as light in the heavy timbers such as pitch-pine, for example, as in the large timbers, such as white pine, the fibrous divisions between the cellular spaces are much thicker in the heavy timbers than in the light.

Continuing the methods of sawing :

Wood for use as floor boards is cut from the log by a method termed

Floor-board Sawing, which is performed by first sawing the log down its length into thirds, and then sawing these thirds across and discarding the four outer portions of the two outer thirds and the centre (which contains the pith and heartwood) of the centre third.

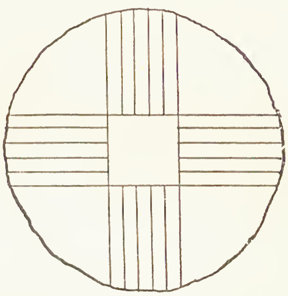


Fig. 5.—Floor-board sawing.

Plywood and Veneer.—For this a portion of the log is placed in a large lathe which is fitted with a cutting blade the same length as the lathe. The log is then shaved off in its whole length, and sheets of wood are so formed of a surprising thinness and in a continuous length.

For veneer these thin sheets are glued and pressed in a single thickness on to the face of a cheaper wood ; whilst plywood consists of several thicknesses of these sheets glued and pressed together, each alternate sheet being placed so that the direction of the grain is reversed from that of the sheet adjacent to it.

Definitions of Terms used in Conversion.—*Timber* may be used in description of the growing wood, or of the wood when sawn into sizes. A distinction is made in this matter in Canada and U.S.A. by applying the term " lumber " to trunks when felled.

A Log is the trunk of the tree after the branches have been lopped and the bark has been stripped.

A Balk is a squared timber at least 12 inches each way, and not often more than 18 inches one way.

Whole Timbers are logs from 9×9 inches to 15×15 inches.

Half Timbers are logs from $9 \times 4\frac{1}{2}$ inches to 18×9 inches.

Quartering are logs from 2×2 inches to 6×6 inches.

Planks are generally 11×3 inches.

Deals are 9 × 3 inches.

Boards are 7 to 9 inches × 2 inches.

Battens are $4\frac{1}{2}$ to 7 inches × $\frac{3}{4}$ to 3 inches.

Strips and Laths are 4 to $4\frac{1}{2}$ inches × $\frac{1}{2}$ to $1\frac{1}{2}$ inches.

Scantling is another term used in a dual sense. A scantling may be a timber 4 × 6 inches to one 12 × 12 inches, or it is the term used in speaking of the dimensions of any cut timber in such an expression as "the timber to be of the following scantlings," in which sense it is often used in specifications.

Masts have, technically, a circumference of more than 24 inches.

Spars and Poles are of less circumference than masts.

Ends are short pieces less than 8 feet in length.

DEFECTS IN TIMBER

Whilst it is commonly stated that timber which is grown slowly is stronger than that which grows quickly, this, as has been explained, is not always so, and the matter depends on the class to which the tree belongs.

The defects in timber are divisible into those having their origin in disease, those arising from accidents or during improper conditions of growing, and those which are occasioned by unsatisfactory seasoning.

Diseases.—There are two types of diseases of trees: those which affect the tree during growth, and those which affect the timber after it has been cut and used in building or manufacture.

The first of these, though possibly not exactly a disease, but a defect causing the timber to be unsuitable for constructive purposes, is *Decay from Old Age.* This begins at the heart in living timber past a certain age and at periods varying with the conditions of soil and atmosphere in which the timber is growing. The best-known example of such decay is to be seen in the elm, which becomes with age hollow in the centre. Elms, however, are known to exceed 500 years in age, so that it would not appear that this defect shortens the life of the tree.

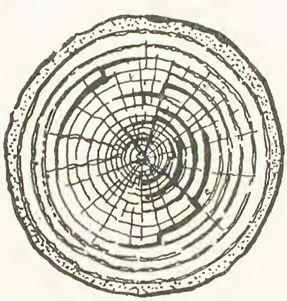


Fig. 6.—Cup shakes.

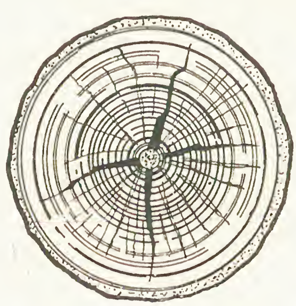


Fig. 7.—Heart shakes.

Cup Shakes is a defect caused by the freezing of the water contained in the trees, with the result that cracks appear between and following the curve of the annual rings.

Heart Shakes are cracks radiating from the pith outwards in a star-shaped pattern running through the heart of the tree. These are the first stages of the decay from age mentioned above.

Knots, though not a disease in any sense, are a defect in timber when used in building, as they cause weakness, especially if large, loose, or dead.

In decorative work, however, knots are an advantage owing to the variation of colour and texture which they create. The cause of knots is a natural one, being the junction of branches with the stem of the tree.

Upsets are crushings and breakages in the fibres of a tree caused by blows, such as one tree falling on another might cause. These are, if severe, a source of weakness in timber.

Rhind Galls are another defect of malformation caused in the growing tree when branches are improperly lopped. The rhind gall appears as a swelling, as if it were an attempt to cover up the wound with a growth which becomes excessive. This growth is not composed of fibres similar to those composing the healthy timber, and is often spongy.

Quagginess is the term descriptive of a condition in which the centre of the tree, when felled, is found to be filled with shakes and clefts.

Foxiness is an indication of decay in its early stages, and is to be seen in yellow to dull red streaks or stains; whilst in

Druxiness the decay appears as whitish streaks or spots.

Doatiness is another form of decay of a localised nature appearing in beech and American oak as a speckled stain. This is most frequently seen in the timber after it has been seasoned when the seasoning has not been completed satisfactorily.

Fig. 8.—Wind cracks.

Twisted Grain showing in the timber when cut is caused by a prevalent wind blowing the tree top round in the same direction during its early years. Owing to the increased fibre cutting necessitated, such timber does not work well for squaring, but is useful in masts and poles, as it gives an added strength against the strains to which such erections are subjected.

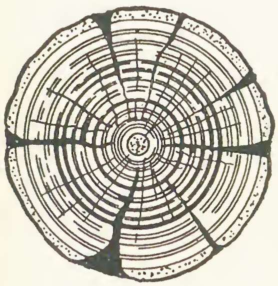


Fig. 9.—Star shakes.

Wind Cracks appear as a crack along the length of the fibres for a short distance only.

Star Shakes are to be distinguished from heart shakes in that, though they radiate similarly from the centre outwards, they are widest at the circumference. This is a defect causing weakness, and originating from defective seasoning when the outside edges are dried too quickly, and thus caused to contract more than the interior, with the result that the fibres of the outer surface become stretched beyond endurance and split, from outside inwards.

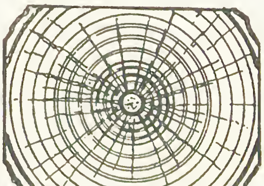


Fig. 1 .—Waney edges.

Waney Edges are caused when a log is squared to dimensions too large for the square measurement of the tree, the corners being within the square and consequently having the waved outline of the tree stem.

A Sour Smell and a woolliness in working when

being sawed is an indication of disease. Such timber will, when struck, give out only a dull sound, if any.

A Preventive Measure against checking and surface cracking during seasoning is to paint the ends of the timbers with a preparation composed of the following ingredients :

Asbestine . .	25 per cent.	
Barytes . .	25 per cent.	
Hardened Gloss Oil	50 per cent.	Naphtha 35 per cent. Rosin 60 per cent. Lime 5 per cent.

One gallon of this preparation, as recommended by the United States Forest Products Laboratory, will be required to cover 100 square feet.

The practice, often resorted to, of nailing wooden strips across the ends of unseasoned timbers to prevent splitting is not recommended by our Forest Products Research, as they state that "it may actually, by hindering the normal contraction of the wood as it drys, cause a worse split than would otherwise happen." It is further stated that "the force exerted by this contraction is well demonstrated by considerable buckling which occurs in the toothed metal strips often used instead of wooden strips." It is recommended, however, that "after contraction has taken place, a wooden strip (or S-iron in the case of timbers) may be useful in preventing further development, due to seasonal changes in moisture-content, of any splits that have arisen during drying."

Collapse is a condition in which the water has been drawn too rapidly from the wood in air-seasoning, but more likely in kiln-drying, for the air in sufficient quantity to replace it quickly enough, with the result that the cellular walls are drawn together as the water is extracted.

Dry Rot.—Of diseases that timber is subject to the worst is *Dry Rot.* This is an infectious fungoid growth which originates in a germ. Certain conditions must obtain to enable this germ to grow, and consequently in preventing these causes lies the remedy. It should be distinctly understood that in the two kinds of dry rot most prevalent the actual cause itself is a living organism, the result of which is a powdering or crumbling away of the wood, and from this point of view the disease might be thought to be wrongly named, and that it would be more appropriately called wet rot.

Wet Rot, however, is a condition of decay occasioned by the timber being subjected alternately to conditions of wetness and dryness and is not infectious, as is the subject now under consideration.

The main conditions necessary to enable the germs of dry rot to grow are : (1) an excess of sap in the wood ; or (2) imprisoned moisture from other causes ; (3) both confined in spaces improperly ventilated and warm and moist ; (4) once any timber has become infected with dry rot it is a source of infection to any other timber in its neighbourhood.

Indications of Dry Rot are firstly, a musty smell, and secondly, a spottiness or a fine network of threads appears on the surface of the infected timber. Later, these develop into hanging fungoid growths, or a thick network, according to the class of dry-rot germ.

The disease may originate in the timber whilst it is in the forest if, after it is felled, it is left in damp conditions for some time. It will later disclose its presence by appearing as red stripes in the timber when sawn, but this can be cured during seasoning if the operation is thoroughly performed. Partial seasoning, however, has the effect of strengthening the growth, and if sap or other moisture is left in the wood and the wood built in in unventilated conditions, where damp is also present, active growth will soon begin.

The following notes taken from an official leaflet issued by the Board of Agriculture render the detection of this infection a simple matter :

" The fruit of the dry-rot fungus presents the appearance of irregularly shaped, flattened, or undulating patches of variable size, adhering by their entire under-surface to the substance on which they are growing. When mature the central portion of the patch is covered with an irregular network formed by slightly raised anastomosing ribs, and is of a rich brown colour, due to the enormous quantity of spores which are deposited on surrounding objects in the form of snuff-coloured powder. These spores are diffused by currents of air, or by rats, mice, and insects.

" The margin of the fruiting-patch is surrounded by a snow-white fringe of mycelium which spreads in every direction over surrounding objects, creeping up walls, and passing through crevices, the advancing mycelium being supplied with food and moisture from the parent plant growing on the wood.

" This food is conducted through cord-like strands which form behind the thin advancing margin of mycelium.

" Owing to this supply of food from a central source the mycelium can extend over stones and other substances not containing food, and thus spread from the basement to the top of a house. Each time the migrating mycelium comes into contact with wood the latter is attached and a new centre of food-supply is established, from which strands spread in search of other sources of food. The mycelium often forms felt-like sheets of large size that can be readily removed intact. These sheets are white at first, but soon change to a pale grey colour—a character by which dry rot can be readily distinguished from another wood-destroying fungus, *Polyporous fomentarius*, even in the absence of fruit, the felted mycelium of the latter being permanently white.

" The specific name of *lacrymans*, or ' weeping,' alludes to the power of the fungus to attract moisture from the atmosphere. Under certain conditions, moisture is absorbed to such an extent that it hangs in drops, or even drips from the surface of the fungus. This moisture assists very materially in rotting the timber, which afterwards becomes dry and

friable. Hence the popular name ' dry rot,' which alludes to the last and most frequently observed stage of decay."

The greatest trouble in connection with this disease is that the first indications of its presence are often not noticed until it has got such a hold that the time has passed when the usually advised remedies will prove effective. For instance, dry rot in the joists of a floor may develop into such an advanced condition that the first indication given of its presence is that the floor collapses at some point. It is then, of course, too late to consider seasoning or any such initial precautions ; and from what has been said above concerning the spreading powers of this disease it becomes a question if even cutting out all the obviously infected timber will be effective in preventing a spread that may have extended all over the building. In fact, the only proper remedy to take when " dry rot " is discovered anywhere in a building is to spray all the timber remaining after the decayed timber has been removed with one of the preservatives mentioned later.

The usually recommended precautions against dry rot are to use, in the first place, only well-seasoned timber, free from much sapwood, and to arrange for air-currents around all timber, especially built-in timber such as floor joists, beams, and rafters, and not to paint any unseasoned or damp wood.

Of all the preventive measures advised, probably ventilation, in the first place, of the positions into which the woodwork is built is the most important. It should be remembered that dry-rot fungi cannot grow without moisture and warmth. This is a matter concerning the design of construction, but it may be accepted as a very general rule that an air brick is never amiss. Concerning this point the Royal Institute of British Architects advise :

No timber should be used in such a position that the moisture in and around it cannot be readily evaporated, as, for example, if floors are constructed of solid concrete (with or without steel), wood fillets should not be nailed underneath to receive the ceiling.

No wood steps should be built into or on the top of concrete and afterwards covered with an impervious floor, and no wood boards should be laid direct on the concrete and afterwards covered with an airproof material such as linoleum, oil-cloth, etc.

All ground under a wooden floor should be cleared of any vegetable or fungoid growth and covered with cement, concrete, or asphalt, and this should be left as long as possible before any joists or flooring are laid.

No wooden pegs communicating with the earth beneath should be left in and through the covering over the earth.

Provision should be made for the abundant introduction of fresh air underneath all parts of suspended ground floors by means of inlets, and particularly at all angles, so that cross currents may be induced.

The concrete under floors should be thoroughly cleared of all small

pieces of wood and shavings, as it has been found that the spores in these pieces of wood, drawing the moisture from the concrete, have been a means of spreading the disease.

In upper floors of wooden joists, if a pugging be inserted for sound-proofing it is suggested that this be of some dry substance, such as slag-wool, but in no case must an impervious material be used for the ceiling beneath or the floor covering above.

Damage from Insects.—Another cause of damage to which woods are subjected is attack by *Ants and Beetles*. Of these, that from beetles is the most serious in our country, the termites and white ants belonging to tropical and sub-tropical countries. Of the beetles, those known as the *Longicorn* and *Pin-borers* attack the timber in the forest just after it has been felled, and when it is seasoned they leave it. The powder post and furniture beetle attack seasoned timber in the timber yards and in buildings and when made into furniture.

Of the *Longicorn* the eggs are laid in the crevices in the bark, and when hatched out the caterpillar, or grub, bores a tunnel in the tree until the time comes for its change into a chrysalis, when it enlarges the end of the tunnel into a chamber near the surface of the wood. The end of this it closes with bark until it emerges as the beetle. It is clear, therefore, that it is the grub which does the damage to the timber, and a preference is shown for unhealthy timber.

Their prevention is hardly within the province of the builder, though if timber is bought in the stack, it should be examined for these borings which are often to be seen on the surface. The barking of the trees, already referred to, is a preventive measure, as then the eggs are removed with the bark; and this and removing the logs soon after felling have proved more effective than any form of spraying.

Pinhole Borers bore deeply into the wood of trees, feeding, not on the tree, but on a fungus which grows in their tunnels. However, the damage consists in the boring, and an indication of the presence of these beetles in a tree is to be seen in the holes bored in the bark by the female in which she lays her eggs. The tunnels are continued into the tree until the sapwood is reached, and in this tunnel, or enlargements of it, the whole life-history of the beetle in its four stages is lived.

These insects, also, attack the timber immediately after felling. Seasoning prevents further attack, as it kills the food fungus. They are found in oak, ash, hickory, and other hardwoods. The remedy is the same as that mentioned above.

The Powder Post Beetles will be more the builder's concern, as they attack seasoned timber; and of these that known as the *Lyctus* is the most important. It is found only in hardwoods and those recently seasoned, oak, ash, hickory, and walnut being the chief sufferers. The beetle lays her eggs in the sapwood by injecting them through a sharp probe. The grub feeds on the sapwood and enlarges its chamber by gnawing as it grows. When fully grown it gnaws its way to a point near

to the outside, where it forms a chamber in which to undergo the change into a chrysalis from which the beetle emerges.

The destruction may result in the complete exhaustion of all the sapwood, and the external indications are the holes and dust from them.

The remedies advised are the removal of the sapwood ; sterilisation by heat and certain insecticides, such as zinc chloride, sodium fluoride, and sodium silico-fluoride.

Furniture Beetles attack furniture, panelling, and open roof timbers in both coniferous and hardwoods, and in the heartwood as well as the sapwood. The beetle itself is only about a tenth of an inch in length and is to be found crawling in walls and ceilings. They lay their eggs in crevices in the wood and the young grubs bore into the wood, following the grain of the wood when a slight depth is reached. The dust from their borings is the accepted indication of their presence within. As with the other beetles, an enlarged chamber is made for the chrysalis transformation, and in this consists the chief damage.

The Death-Watch Beetle is perhaps the best known of the beetles which attack woodwork in a building, favouring in particular the timbers of an open roof, trusses and beams. The publicity which this beetle has gained arises mainly from the fable that the sound of tapping which it makes is the sign of death, which may be true if the beetles are allowed freedom to continue their ravages long enough, as they will hollow out even large beams, with the obvious result that the beam and anything that it supports will fall. The real explanation of the tapping, however, is that it is the female's method of calling her mate, and is performed by the lady's head knocking against the wood. The matter is of practical interest, as it affords a means of discovery before the destruction has gone too far. That this destruction may be of a very serious nature was to be seen in the condition of approaching collapse to which the roof of Westminster Hall was reduced. There some of the main trusses were almost hollowed out in parts, and there was very great danger, at the time of discovery, of collapse.

The life-history of this beetle is similar to that of those already detailed. The most successful prevention is sterilisation before use of the timber, and when the timber is built in, treatment with turpentine, heavy paraffin oils, and zinc chloride ; chloride and benzine is recommended. Four annual applications should be made. The preparation used under the direction of Professor Lefroy at Westminster Hall in conjunction with the structural repairs carried out under Sir Frank Baines was of the following prescription :

Ortho-di-chlor-benzine	91 parts.
Castile soap	7 parts.
Cedar-wood oil	2 parts.

The woodwork was dusted with vacuum exhausts, and then sprayed with the preparation, the sprayer having a fine nozzle and being worked under high pressure.

Marine Worms also attack wood, boring holes right through the wood. Creosoting is the usual preventive.

THE PRESERVATION OF TIMBER

The methods employed in preserving timber from decay and attack by insects and parasites consist of a variety of forms of either of two operations. The first is treatment by heat, and the second is treatment by the injection of some chemical preparation found to be destructive of insect and parasitical life. The oldest form in which heat is applied is the method of—

Charring.—This consists merely in the burning of the ends of timbers, mainly those intended to be buried in the ground for any purpose such as for gate-posts. For this the ends of the timbers are held in a fire until they are charred to about ½ inch depth, when they are taken out of the fire and quenched in water. So far as the prevention of decay in the portion charred is concerned, the method is effective; but as the charred portion is generally buried in the ground with the top of the charring coinciding with the ground line or just underneath the ground, the result is that the uncharred wood just above the ground line becomes subjected to alternating conditions of dry and wet, which are the most productive conditions of decay (see *Wet Rot* above). The further result of this is that sooner or later the post, having become rotted nearly through at the ground line, breaks off.

The action of this wet rotting consists in the combination of the oxygen in the air with the carbon in the wood to form carbon dioxide (CO_2), and with the hydrogen to form water (H_2O). The hydrogen, however, becomes oxidised more quickly than the carbon, with the result that the carbon is in excess, as is to be seen in the brown dry powder which forms in rotting wood. As water and oxygen are both necessary for this destructive action, it will be seen why conditions of alternating wet and dry are necessary for wet rot.

The formation of a charred coating on the outside of timber is also open to another objection, in that the coating formed being impervious, any sap in the fibres of the wood at the time of burning becomes imprisoned within and later sets up decay. At best, therefore, this method is only temporary, which objection in a greater degree obtains against the alternative practice of—

Concreting.—This consists merely in building the posts in a concrete bed or a foundation completely surrounding the buried portion of the post. The concrete prevents the air from getting to that part of the post which it surrounds, with the same result just mentioned, that the sap moisture is imprisoned and decay sets in. The duration of posts so treated is rather less than those charred; and they invariably break off at the top of the concrete surround.

From the two foregoing methods, therefore, it will be clear that, in

order for the preservation of the timber against decay, it is essential that the internal moisture must be completely expelled, and that the fibres so freed must be rendered permanently resistant to any further ingress of moisture. This expulsion is carried out by pressure, and the expelled moisture is replaced by suitable chemicals also driven in under pressure. Such heat processes have also the effect of killing any insect, grubs, eggs, or pupa, and also the destruction of the means of existence of any dry-rot fungus.

Burnettising is perhaps the best-known method of injecting chemicals under pressure, resulting in a more or less complete impregnation. The operation is carried out in steel cylinders, and consists in the forcing of a solution of zinc chloride ($ZnCl_2$) through the fibres of the wood from end to end, under considerable pressure. This results, not only in driving out the natural moisture and in replacing it with a chemical resistant, but also in the destruction of any parasitic growths or insects in any form.

Other methods of a similar nature are :

Bethels, in which the timber, placed in similar cylinders, is impregnated with creosote, or oil of tar, from which the ammonia has been expelled. In order to ensure a complete penetration the air is exhausted from the cylinders, and the creosote is forced in at a pressure varying from 60 to 160 pounds to the square inch according to the weather conditions.

In the *Blythe method,* carbolic acid is used in a similar way, after the sap has been dried out ; whereas—

In the *Boucherie method* the sap is expelled by the injection under pressure of the fluid, in this case copper sulphate.

Another method of injection after the sap has been dried out is the *Ferrell,* in which ammonium sulphates and chlorides are injected.

Kyanising consists in immersing the timber in a solution of corrosive sublimate, with the result that an insoluble compound is formed with the mercury bichloride and the albumen in the timber.

STERILISATION BY HEAT

The subject has been scientifically investigated at the Forestry Products Research Laboratories at Princes Risborough, with a view to proving its usefulness in ridding timbers from attacks by destructive insects such as have been mentioned above.

As some of the beetles attack the timber before it is manufactured into articles of furniture or used in building, and as some of the parasitical fungoid growths originate when the timber is left lying in damp conditions after felling, it is clear that the operation of sterilisation by heat should be undertaken before the timber is used.

It would seem that in sterilisation by heat is to be found the most economically sound method of ridding timber of these destructive agencies. In fact, the Research Board's Report, 1928, states that were timber sterilised immediately before use, the loss caused would be reduced at

once. This method, for the destruction of wood-boring insects, has been in vogue in the U.S.A. for some years. Two satisfactory methods are recommended:

"*Dry Heat Treatment,* in which the timber should be subjected to a gradually increasing temperature until 149° F. is reached. This temperature must be maintained for two hours for 1-inch thick material, allowing an additional hour for every inch above." But as this treatment is liable to cause warping, and affects the mechanical properties of the wood, it is not so successful as the—

"*Moist Heat Treatment,* in which the timber should be gradually moistened, and then subjected to a temperature of 150° F. for two hours, allowing an extra hour for each additional inch of thickness above 1 inch."

Further exhaustive experiments were carried out at the Research Station which go to prove that if sterilisation were combined with kiln seasoning in timber yards, the practice would result in the freeing of any timber from insects, but that as timber so freed is liable to reinfection at a later date if kept in store for a long time, the process of sterilisation should be repeated before use of the timber in manufacture.

PRESERVATION BY CREOSOTING

Creosote in some form is the basis of a variety of preparations for the preservation of timber. It is most satisfactory when used on softwoods and for use when the appearance is not to be considered.

Impregnation by creosote is carried out in a similar manner to that described above, the timber being placed in metal cylinders from which the air is extracted and the sap is thus removed. Creosote oil is then driven in under a pressure of from 80 to 140 pounds per square inch.

Brush treatment gives protection for about twelve months only in positions exposed to moisture and air.

PROPRIETARY WOOD PRESERVATIVES

Some proprietary preservatives consist chiefly of coal-tar creosote of the best quality. Creosote varies in quality and the cheaper unbranded makes are not so potent and lasting in effect as the best proprietary makes.

Other preservatives consist of metallic salts which are deposited in the pores of the wood and being insoluble and stable do not evaporate or deteriorate. With most of these preservatives surface treatment by brush or spray is considered to be adequate.

Before adopting a proprietary preservative for important work it is advisable to study the maker's description and claims, and records of authoritative tests.

CHARACTERISTICS OF GOOD TIMBER

Sound Timber may be known by its freedom from any of the foregoing defects and from its healthy, clean appearance, and the ease with which

it works. When sawn there should be none of the woolly appearance or dampness in the sawdust, and the perfume given off should be sweet instead of sour. When struck with a hammer it should give a distinct ring in place of the dull sound emitted by a decayed timber, and though not living in the sense that it is when growing, the appearance of the fibres should denote a state of life in contrast to the dead wood in decayed or decaying timber. The cellular tissue of the medullary rays should be distinct and " lively," though, as has been explained, the rate of growth and strength cannot be ascertained from the closeness or otherwise of the annual rings.

STRENGTH OF TIMBER

The Strength of Timbers will be found to vary even in those of the same class, as this characteristic depends upon certain conditions during growth, felling, and seasoning. Also, as was pointed out, the strength of any portion of the log will vary with the condition of the part of the log from which it was cut, *i.e.* whether the part cut contains mostly sapwood or heartwood. The amount of moisture present in timber also has an effect on the strength, and, of course, the presence of any of the defects or flaws will result in weakness.

In consequence, the figures hitherto published on the strength of timbers can be taken only as average figures. For this reason, and that more exact particulars might be ascertained with a view to revising the existing specifications for building timbers, conferences have been held between a sub-committee of the R.I.B.A. representatives of the Timber Trades Federation of the United Kingdom, and of the Building Research Station and the Forestry Research Board. The existing specifications were, for the most part, out of date, and called for brands and varieties no longer existing owing to changes in the conditions and supplies of timber.

This revision was intended to supplement that carried out by the laboratory for H.M. Office of Works, the Ministry of Health, the Air Ministry, and the Ministry of Home Affairs with a view to arriving at a Standard Specification for Timbers used in building.

CLASSIFICATION OF TIMBER

The timber used in building is classified under two main headings—*Softwoods* and *Hardwoods*. All the conifers, such as pines, the firs, and yew, belong to the former, and the deciduous trees, *i.e.* those that shed their leaves in the autumn, belong to the latter class. These include oak, mahogany, and teak, the hardwoods most used in building, also the ash, beech, chestnut, ebony, elm, and maple, mostly used in allied industries.

Softwoods may be known from the fact that in the section the annual rings are generally wider apart than in the hardwoods, in trees grown under similar conditions ; and from the resin, which is to be seen at the outside of these rings. The medullary or wood rays will not be readily seen, nor can the heartwood be distinguished from the sapwood, as there

is very little difference in the colour of the two. Though in this matter, what has been already said with regard to the rate of growth and the formation of the rings in the same class of timber should be recollected. A slow-grown coniferous timber is generally stronger than a quick-grown, and in the former the space between the rings will be much narrower than in the quick-grown tree.

However, in a hardwood such as the ash for instance, the quick-grown, with its wide annual rings, is stronger than the slow-grown, with its narrow rings. This is because the former has a greater proportion of dense summer wood than the latter.

Hardwoods are distinguishable by the marked medullary rays, and the pores in the fibres are more defined. These " pores " are wide short cells, linked together throughout the height of the tree to conduct the water ; and as they vary in size, they are helpful in classifying the hardwoods into those having large pores, such as the oak, elm, Spanish chestnut, and walnut ; and those having small pores, such as the beech, plane, birch, and poplar.

The above examples, however, show a very considerable variation in the medullary ray markings ; those of the oak, beech, and plane being very conspicuous, whilst those of the elm and walnut, wavy, and those of Spanish chestnut are hardly discernible.

A classification of softwoods and hardwoods as those of light weight and those of heavy weight sometimes given is not sufficiently exact, as an abundance of small pores and consequent thin fibres in between will cause lightness as in the poplar.

Another Method of Classifying the timbers used in construction is : (1) cone-bearing or coniferous, and (2) broad-leaf trees.

Also, it should be noted that in some of the foreign hardwoods a certain amount of resin is to be seen.

WEIGHTS OF TIMBERS

The weights of timbers vary from 25 pounds per cubic foot up to over 50 pounds, the following table giving the approximate weights of the various timbers :

Spruce, Willow, Poplar	25 pounds per cu. foot.
White Pine, Hemlock, Spruce, Chestnut	25–30 per cu. foot.
Pitch Pine, Douglas Spruce, Sycamore	30–35 per cu. foot.
Maple (Soft), Beech, Walnut	35 pounds and over per cu. foot.
Hard Maple, Elm, and Oak	40–50 pounds per cu. foot.
Teak, Mahogany, Lignum Vitæ	Over 50 pounds per cu. foot.

A Classified List of the main timbers used in building, their characteristics and uses, will be found on pages 20–22.

SOFTWOODS

Varieties, Characteristics, and Uses

Name.	Where Grown or Shipped.	Texture.	Colour.	Characteristics.	Uses.
Deal—Scotch fir.	Great Britain.	Straight grained	Light yellow.	Annual rings clearly defined, resinous.	Joinery and constructional.
Deal—Norwegian.	Christiania.	—	Light yellow.	Sappy.	Flooring and match-boarding.
Deal—Prussian.	Danzig-Memel.	Open grained.	Light yellow.	Too rough for finish.	Carpenter's work. Rafters, floor joists, etc.
Deal—Russian.	Archangel.	Closer grained.	Whitish.	Free from sap.	Best joinery.
Deal—Swedish.	Stockholm	Coarse.	Yellow.	Inferior.	Match-boarding.
Pine, American, yellow or white pine.	Quebec.	Straight grain.	Whitish yellow	Medullary rays not visible.	Joinery in mouldings.
Pine, pitch.	Canada and U.S.A.	Straight grained.	Red.	Grows 100 feet high, very resinous.	Heavy construction piles and beams.
Pine, red.	North America.	Fine grain free from knots.	Red.	Works finely.	Internal joinery.
Pine, Oregon or Douglas fir.	West North America.	Straight grained.	Reddish.	Hard, strong, free from knots and shakes and sap.	Imported doors, etc.
Pine, Sequoia.	California.	Straight grained.	White to pale yellow.	400 feet high by 40 feet diameter. Easily worked. Shrinks in length.	Joinery.
Pine, Northern, also Scotch fir (see above).	Russia.	Straight grained, elastic.	Light yellow to pale reddish brown.	Moderately resinous.	General joinery and carpentry.
Pine, Kaurie.	New Zealand.	Silky grain.	Yellowish white.	Light, strong, elastic. Difficult to work.	Piles, ornamental joinery.
Larch.	Germany, Italy, Russia, North America.	Hard and tough.	Yellow.	Shrinks badly.	Heavy construction.
Spruce or white fir.	Norway, Russia, and Sweden.	Sapwood, scarcely distinguishable from heartwood.	Pale yellow to brown.	80 to 100 feet, tallest European. Inferior to northern pine.	Table tops, dressers, etc.
Yew	Great Britain, Europe, India, Canada.	Very fine, even, close-grained. Well figured.	Orange-brown.	Tough and elastic.	Furniture.
Cedar.	Canada, U.S.A.	Fine, even grain.	Red.	Fragrant odour obnoxious to vermin.	Pencils, cabinets.

Hardwoods

Varieties, Characteristics, and Uses

Name.	Where Grown or Shipped.	Texture	Colour.	Characteristics.	Uses.
Oak, English.	Britain.	Coarse, open grain.	Brown with lighter sapwood.	Medullary rays very pronounced. Very tough, rigid, and strong.	Heavy construction, panelling, and furniture.
Oak, American white.	Canada and U.S.A.	Light and spongy.	Brown heartwood, white sapwood.	Not so strong or durable as English.	General.
Oak, Austrian.	Austria.	Straight grained.	Similar to English.	Less distinctive.	Panelling.
Oak, Spanish.	Mexico and North America.	Fine, close grain.	White to light brown.	Figured.	Panelling.
Mahogany.	West Indies and Central America.	Fairly straight grained.	Reddish brown.	Medullary rays invisible.	Cabinet work and internal joinery.
Walnut.	Britain, Europe, and Asia.	Finely figured close grain.	Grey-brown to dark brown.	Takes high polish.	Ornamental joinery, aeroplane propellers.
Teak.	Burma, India, Java.	Straight, open, fibrous grain.	Yellow to light brown.	Obnoxious to vermin. Very strong and durable in damp conditions especially.	Draining boards, flooring, laboratory table tops.
Elm.	England, Europe, and North America.	Twisted grain, coarse.	Brown.	Warps badly in seasoning. Durable in wet or dry conditions.	Coffins, piles.
Ash.	Britain, Europe, and North America.	Streaked.	White to pale brown.	Easily worked. Tough. Flexible.	Tool handles, carriage shafts.
Ebony.	India, Malay, Africa, W. Indies.	Extremely close grained.	Dark brown to black.	Hard.	Inlay carving.
Beech.	Britain, Europe, North America, New Zealand.	Fine, close grain.	White to light brown.	Porous. Works easily. Durable wet or dry.	Piles, groins.
Birch.	Britain, North Europe, Eastern Canada.	Even grain.	Cream to pale yellow.	Takes silky finish.	Plywood, wheels.
Basswood.	U.S.A. and Canada.	Straight grained.	Yellowish white.	Annual rings distinct. Medullary rays invisible.	Cabinet work and carving.
Boxwood.	Britain, Europe, and Asia.	Close, dense grain.	Yellow to brown.	Difficult to split. Takes fine polish.	Scale, rules, and turning.
Acacia.	Britain, Europe, North America.	Hard, coarse, open grain.	Yellow to greenish brown.	Lustrous surface. Durable in wet and dry conditions.	Posts and wall plates, trenails.
Alder.	Britain and Europe.	Fine, even grain.	Brown.	Stains well. Durable under water.	Veneers, pumps, and piles.

HARDWOODS (*continued*)

Varieties, Characteristics, and Uses

Name.	Where Grown or Shipped.	Texture.	Colour.	Characteristics.	Uses.
Lime.	Britain and Europe.	Fine, open grain.	Whitish brown.	Annual rings distinct. Medullary rays invisible.	Carving.
Poplar.	Britain and Europe.	Uniform.	Yellowish.	Easily worked. Moderately durable when kept dry.	Carving and plywood.
Plane.	Britain, Europe, and North America.	Fine, open grain.	Yellow-brown to dark brown.	Easily worked.	Cabinet making.
Chestnut	Britain, Europe, and North America.	Coarse, open grain.	Brown.	No alburnum nor sapwood. Medullary rays invisible.	Roof trusses, posts, and rails.
Hornbeam.	Britain and Europe.	Fine, close, fibrous grain.	Pinkish white.	Difficult to split.	Tools.
Sycamore.	Britain, Europe, North-East America.	Even, lustrous grain.	Whitish yellow.	Annual rings distinct. Medullary rays small. Beautiful figure.	Table tops, panels.
Maple.	North America.	Tough, even grain.	Creamy yellow.	Heartwood light brown. Sapwood yellow. Does not split easily.	Furniture, panelling, wood-block flooring.
Hickory.	North America.	Smooth, straight grain.	Brown.	Very tough, less flexible than ash.	Shafts of tools, wheels.
Jarrah.	Western Australia.	Heavy and close.	Red.	Takes a good polish. Brittle. Resists sea water.	Posts, wood-paving, cabinet-making.
Greenheart.	East Indies, British Guiana, South America.	Fibrous, close, straight grain.	Greenish brown.	Very strong, tough, and elastic. Resists sea worms and white ants.	Piles and structures under water.
Lignum Vitæ.	West Indies, America.	Extremely fine, close grain.	Very dark brown, streaked with black.	Full of resin. Very hard and dense.	Tools, mallet heads.
Whitewood Canary.	Canada and U.S.A.	Fine, clean, but spongy grain.	Pale yellow.	Works easily.	Interior joinery, panelling.
Satinwood.	India and Ceylon.	Fine, lustrous grain.	Yellow to brown.	White sapwood.	Cabinet making.
Satin Walnut.	U.S.A. and Mexico.	Silky grain containing beads of gum.	Reddish.	Takes fine polish.	Cabinet making.
Rosewood.	India.	Even, open grain.	Purplish brown with black streaks.	Faint odour when cut. Takes high polish.	Veneers and furniture.

TIMBER DATA

Deals.—European Deals are from 10 to 22 feet in length and from 8 to 10 inches in breadth.

American Deals are from 10 to 13 feet in length and from 9 to 11 inches in breadth.

Measurement.

Standard	= 165 cu. feet.
A Load of Squared Timber	= 50 cu. feet.
A Load of Unhewn Timber	= 40 cu. feet.
1 Square	= 100 feet super of planking.
1 Hundred	= 120 deals.
1 Fathom	= 216 cu. feet : $6 \times 6 \times 6$ feet.
1 Cord	= 128 cu. feet : $8 \times 4 \times 4$ feet.
1 Load of Inch Planking	= 600 super feet.

CHAPTER 2

CARPENTRY: CENTERING AND SHUTTERING

CENTRES

Centering is a term often wrongly used in description of the temporary carpentry used to support poured concrete work ; it should, however, be confined to that woodwork constructed and temporarily held in position for the construction of and support of arches until set.

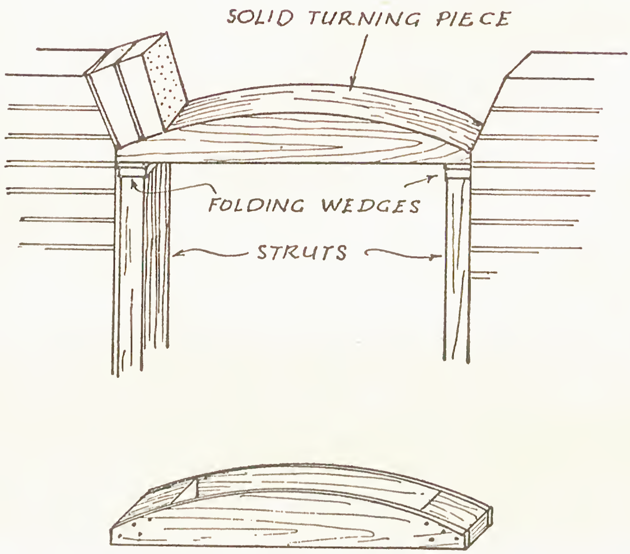


Fig. 11.—(*Top*) Solid turning piece on struts. (*Bottom*) Rib centre constructed of two shaped boards with spacing blocks.

Turning Piece. — A centre composed of a turning piece is the simplest form of centering. This consists of a plank cut to the required shape of the arch to be built, and this is held in position by struts wedged up against its ends. Such a centre is useful only for an arch a half-brick or at most a single brick thick.

Built-up Centres consist of :

Two or more *Ribs* which are shaped sectors of the curve of the arch. These are tied in at their bottom ends by 8 × 1-inch rib ties. And across the tops of the ribs, which may be in series, are run 2 × 1-inch strips of wood which are known as *Laggings* and are spaced about 1 inch apart. Under the ends of the rib ties are run 3 × 2-inch *Bearers* which are supported by 3 × 3-inch posts reaching from the ground or sill of the opening. To ensure a tight fit *Folding Wedges* are driven in either between the tops of the posts and the ties or between the ties and the bearers.

For a brick wall of 9 inches thickness and over the ribbing will be required to be double for wide arches, for tunnels and vaulting, *Brass* and intermediate *Vertical Supports* will be necessary. Also, where the outer

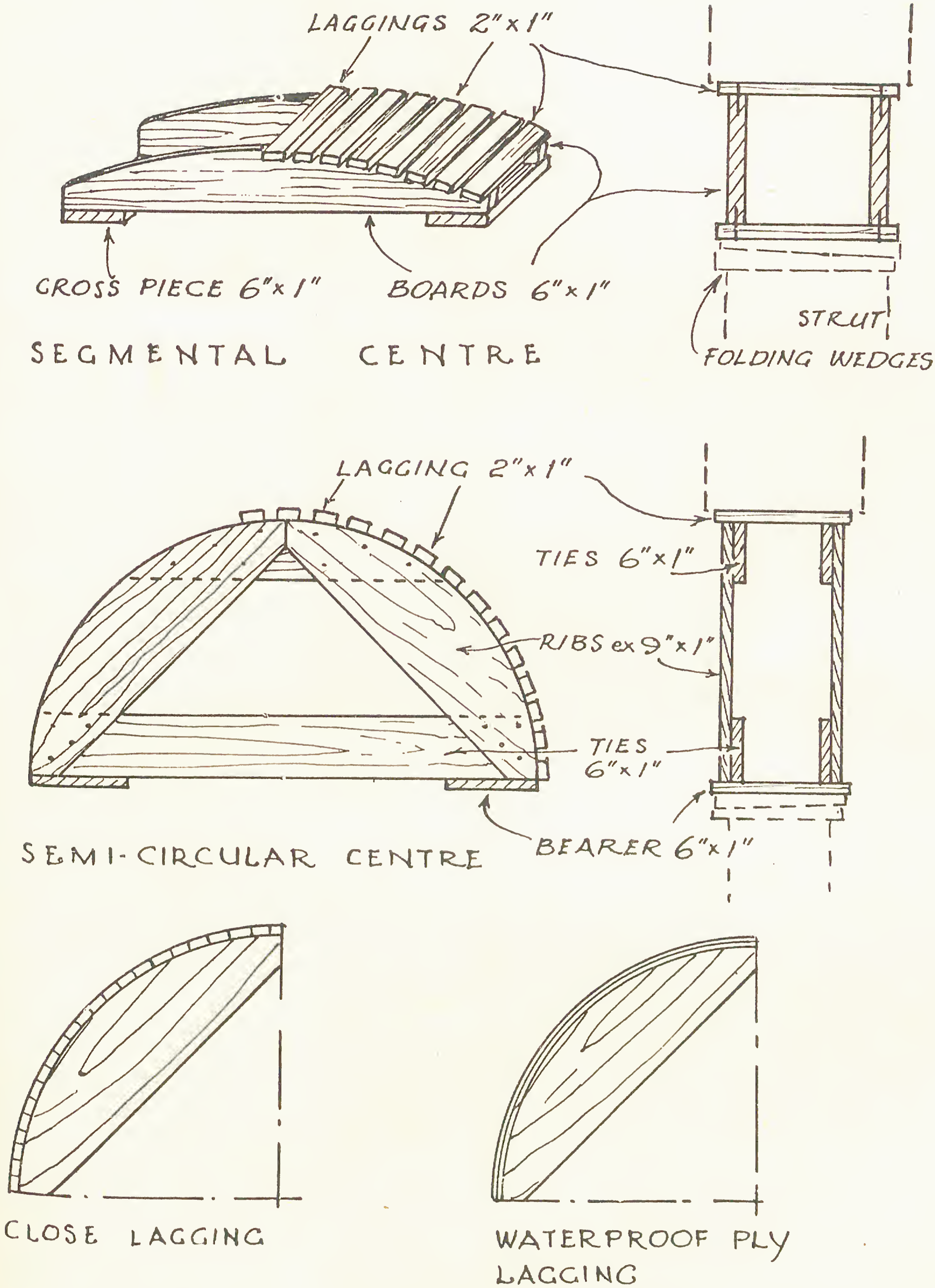


Fig. 12.—Small lagged centres.

arch is struck from a different centre from that of the interior or relieving arch, the centre will require to be separate.

The principles underlying the design and construction of centres for arches are that, being temporary, they should be economical of material and quick to construct. They must, of course, be of sufficient strength to bear the load to be imposed; and there must be a possibility of adjustment. This latter is afforded by the wedges mentioned above. It is also essential that they should be easily dismantled without requiring any undue knocking apart, such as might cause injury and possible collapse of the newly built work above them.

Centres supporting Heavy Masonry are required to be formed of properly constructed trusses with their members jointed with either cut joints or timber connectors.

Such a centre for supporting a stone arch 9 inches thick in a masonry wall would consist of two trusses and be constructed as follows:

The ties would be double and fixed one on each side of the ribs and struts, each tie having a halving cut out to take the tenons cut on the feet of the ribs and in their centres to take the feet of the struts. The doubled ties are cut 6 × $1\frac{1}{4}$ inches, and the centre or King post and struts 4 × 2 inches; the side ribs 6 × 2 inches, and the two centre ribs 6 × 1 inch fixed to the outsides of the side ribs. Under the ends of the ties is run a 4 × 3-inch seating bearer, wedged up with folding wedges out of 4 × 3-inch over the tops of 4 × 3-inch posts. Over the ribs and across them are nailed $2\frac{1}{2}$ × $1\frac{1}{2}$-inch laggings.

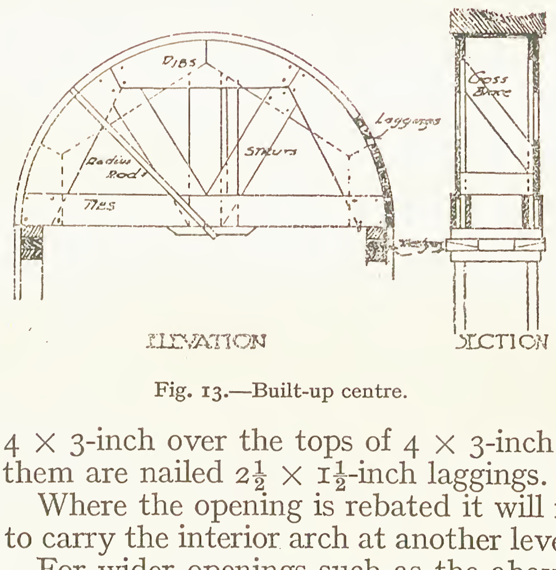


Fig. 13.—Built-up centre.

Where the opening is rebated it will require a secondary set of centres to carry the interior arch at another level from the exterior arch.

For wider openings such as the above, *i.e.* rebated, the centre is built up of ribs in two thicknesses out of 6 × $1\frac{1}{4}$-inch stuff and ties of 7 × $1\frac{1}{2}$ inches, and supported at the centre of the tie with a $4\frac{1}{2}$ × $1\frac{1}{4}$-inch strut. The laggings are 2 × 1 inch spaced 1 inch apart. The inner arch being higher than the outer, the centres are deeper at the springing; but all four centres rest on a 6 × 2-inch seating, wedged up by $7\frac{1}{2}$ × 4 × $1\frac{3}{4}$-inch folding wedges on post bearers run across from an inner and an outer post each 4 × 3 inches.

Centre for Semi-Elliptical Arch.—For a span over 6 feet in an 18-inch wall this centre should be formed of two built-up ribs spaced 12 inches apart and carried on a truss consisting of two 6 × $1\frac{1}{4}$-inch ties, a 4 × 2-inch King post, and a 4 × 2-inch raker or brace run from the top of the

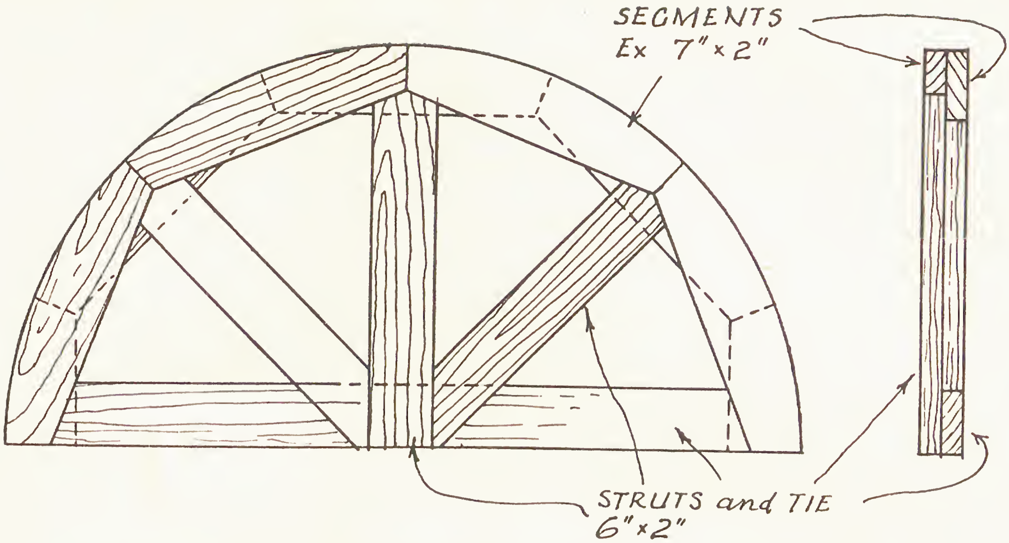


Fig. 14.—Laminated rib centre for shallow face arch.

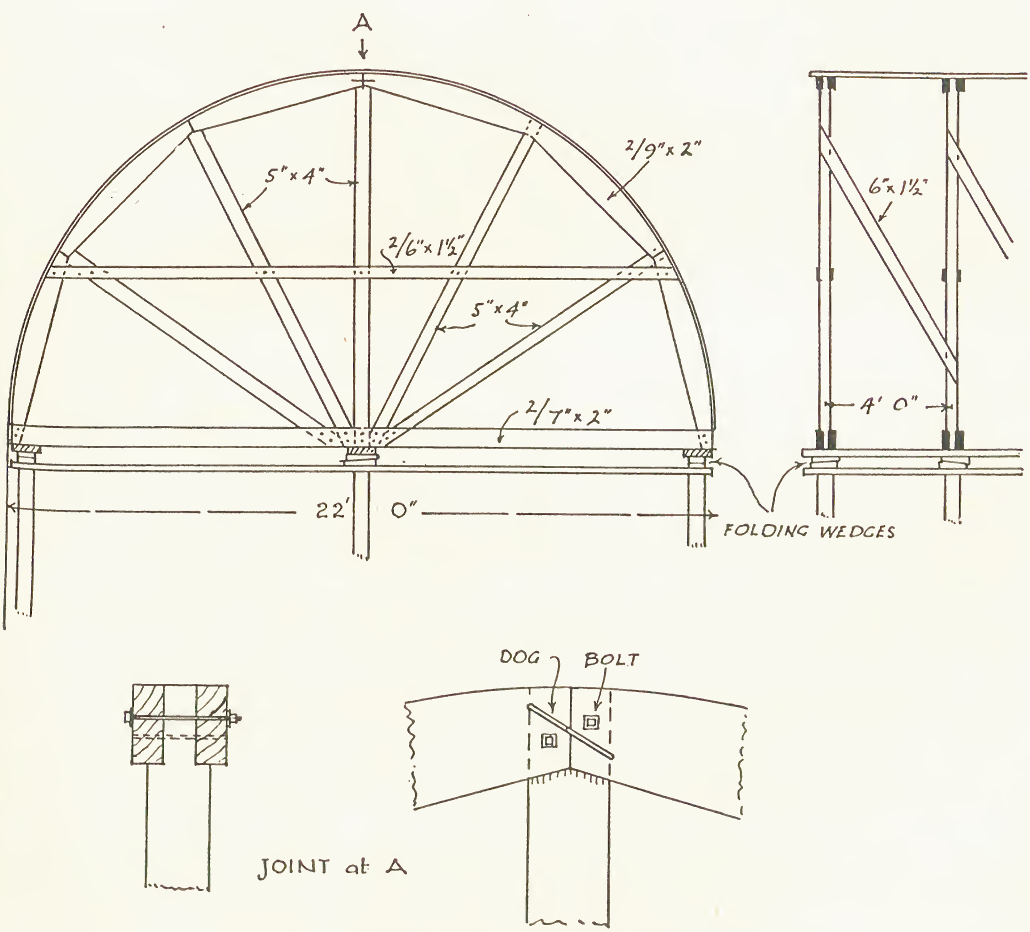


Fig. 15.—A framed centre for a brick arch bridge, 22 feet span.

King post to the end of the tie. From the centre of this and at right angles to it is a 4 × 2-inch strut supporting the junction of the built-up ribs. The sections of the ribs are halved, and a 4 × 2-inch cross stay is nailed from the head of one King post to that of the other, to keep them the correct distance apart whilst the 2 × $1\frac{1}{4}$-inch laggings are fixed.

Easing Centres.—For the purpose of easing the centres described above, so that the weight of the masonry or brickwork built above may be gradually transferred, the folding wedges mentioned are inserted. These wedges also enable the centre to be struck without damage being caused to the arch or abutments, the wedges being gently loosened.

Steel Centres are to be obtained having their ribs formed of rolled-steel joists with the top member bent to the required curve. They are adjusted by screw jacks in place of the wedges described above.

WOOD LINTELS

For *Flat-headed Openings* wood beams called *Lintels* are used where the weight is not sufficient to require an arch, or in conjunction with a relieving arch formed over the lintel to carry the weight of the wall above.

Where the wall over is only $4\frac{1}{2}$ inches thick with no upper storey, a $4\frac{1}{2}$ × 3-inch deal lintel will be found sufficient if the span is not greater than 4 feet. The lintel is laid flatways on the walls, on which it should rest at least $4\frac{1}{2}$ inches at each end.

For *Wider Openings*, and in thicker walls, the lintel must be built up, and should have a relieving arch over it. The lintel may be composed of two 6 × 2-inch deals set on edge and kept apart the required distance by 4 × 2-inch distance blocks. Solid timber could be used but it is unnecessary and would be uneconomic.

CONCRETE SHUTTERING

Shuttering or formwork provides temporary supporting forms of the shape and size desired in the finished concrete construction. It must be strong enough to provide adequate support without excessive deflection until the concrete has set, and it must be so constructed that it can be readily erected and removed.

Shuttering may be of specially constructed timberwork cut and fixed by the carpenter, or of patent metal forms which are of sectional construction and can be readily put together and removed. The sheeting is usually temporary, but sometimes a material is used which can be left in position as a permanent facing.

TIMBER SHUTTERING

As this is temporary work of a strictly utilitarian nature, the carpenter is not called upon to make elaborate joints or to provide highly finished work. Adequate strength combined with easy means of removal are the two factors which the carpenter must bear in mind.

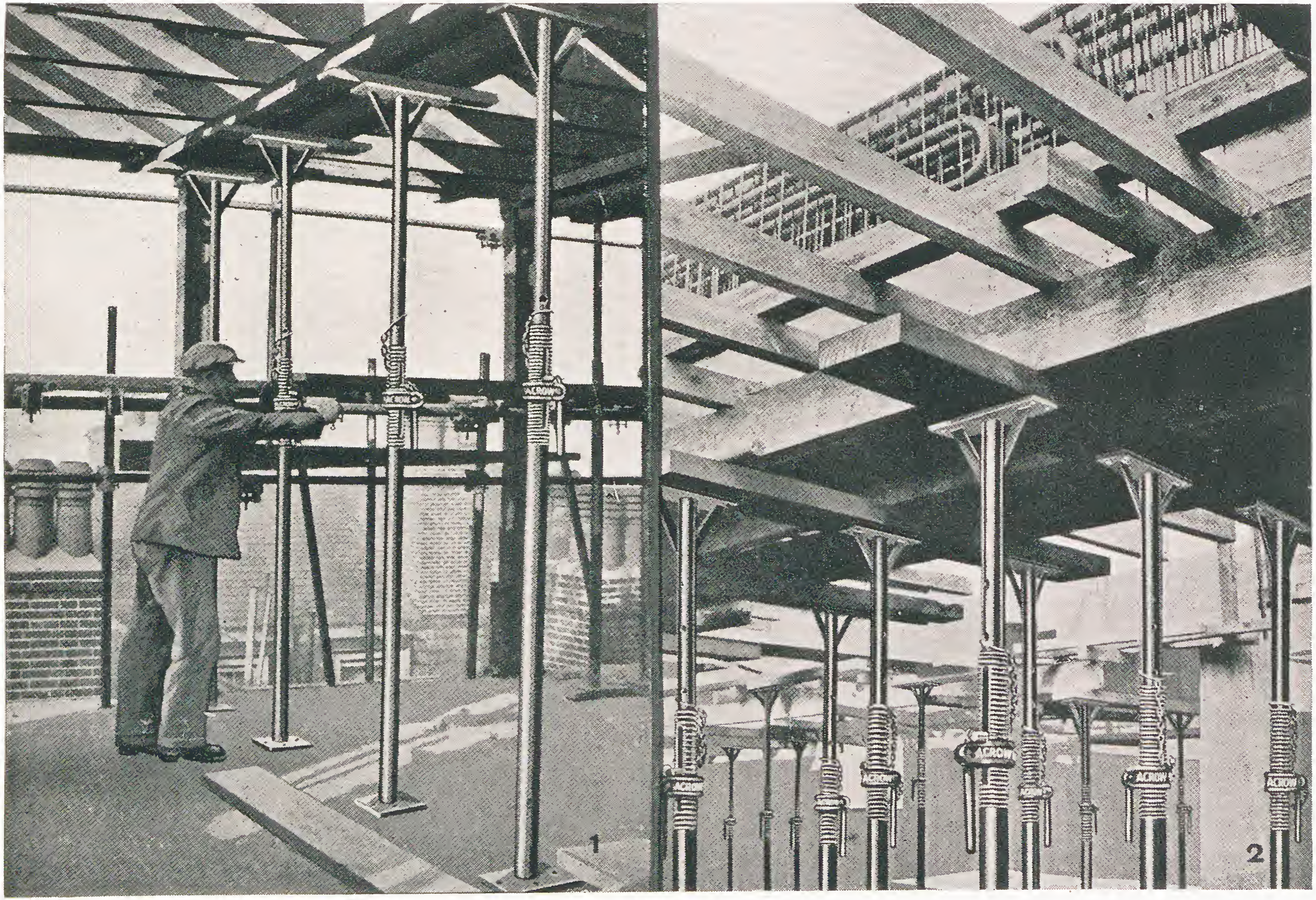


FIG. 16.—(*Left*) ACROW ADJUSTABLE STEEL PROPS. (*Right*) ACROW BEAM PROPS IN HEAVY CONSTRUCTION.

The following outline of good practice is quoted by permission of the British Reinforced Concrete Engineering Co., Ltd.:

Essentials.—The essential features of formwork are strength and stiffness, ease of removal, repetition in use as many times as possible, accurate fixing true to line, adequate propping, bracings, and supports to carry the weight of the newly placed concrete and to protect it from vibration until it has matured.

Slabs on the Ground.—For slabs on the ground or on filling the only formwork required is for screeds from which the concrete can be levelled. These should be of the correct height and should have their edges trued up. They should be rigidly fixed by means of stakes driven into the ground so that when used as end forms they will give clean vertical joints in the floor.

Suspended Floors.—For the purpose of formwork, suspended floors may be considered as of three different types:

1. Floors supported on R.S. Joists where the underside of the floor rests on the top flange.

2. Floors carried on R.S. Joists which are to be haunched with concrete.

3. Floors carried by reinforced concrete beams.

Each type requires a different style of formwork.

1. *Floors Supported on Top Flanges of R.S.J.s.*—This is the simplest type of floor to deal with, the work usually being carried out by placing longitudinal timbers on each side of the lower flange of the supporting joists. Bearing on these and spanning between the R.S.J.s are placed temporary timber joists, the tops of which are arranged so that the close boarding when laid over them will have its upper surface at the level of the underside of the concrete floor slab. The size of the longitudinal timber packing on the bottom flange of the R.S.J.s is arranged to bring the boarding to the correct levels. The size of the joists is dependent on the spans, and their spacing on the thickness of the boarding and thickness of concrete it has to carry. As a typical example, for a 6-foot span with a 4-inch floor, 1-inch boarding would be suitable resting on 6 × 2-inch timber joists placed at 2 feet 6 inches centres.

2. *Floors Carried on Haunched R.S.J.s.*—For this type of floor the formwork may be propped up from the floor or ground below or may be hung by means of hangers from the R.S.J.s themselves, the holes left when the hangers are removed being made good afterwards. When propping is used the method employed is similar to type 3, given later, but as in the majority of cases this is a more expensive and less convenient method, it is not usually adopted.

There are various ways of using hangers, but they vary only in detail. A typical arrangement is shown in Fig. 17. At their lower ends these bolts support timbers on which is built up an arrangement of boarding

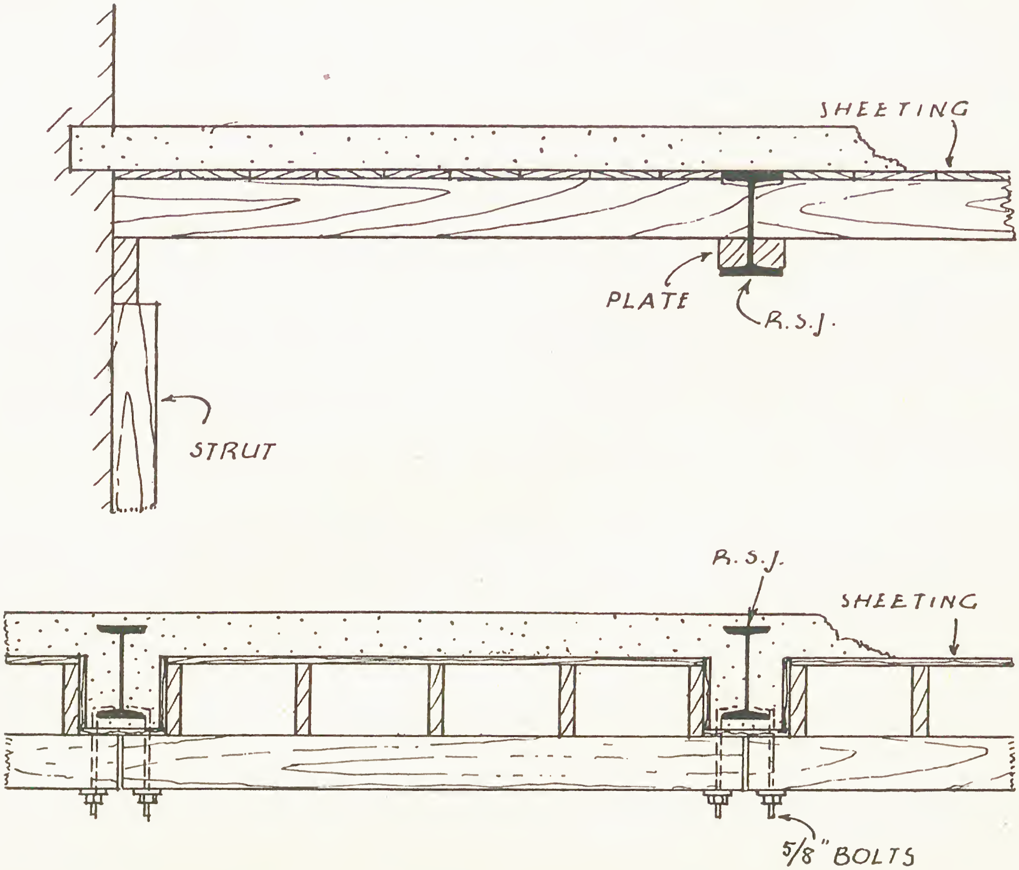


Fig. 17.—(*Top*) Concrete floor on top flange of R.S. joists. (*Bottom*) Concrete floor on haunched R.S. joists.

and joists. The hangers also serve to support the haunching or casing of the R.S.J.s.

3. *Floors Carried on Reinforced Concrete Beams.*—Where a floor is constructed entirely in reinforced concrete, *i.e.* where both beams and slabs are of reinforced concrete, they are usually concreted simultaneously and the whole of the formwork is supported from below by means of props. A typical detail of a bay of such formwork is shown in Fig. 18, which is self-explanatory.

It is of first importance in the arrangement of formwork that all props shall rest on folding wedges so that they may be easily adjusted to level and easily dropped to facilitate removal of the formwork after the concrete has set unless patent adjustable shores are used.

When formwork is propped from the ground great care should be taken to obtain an adequate bearing area for the pole plate. Levels should be checked immediately before placing the concrete and at intervals until the concrete has developed sufficient strength to carry, in

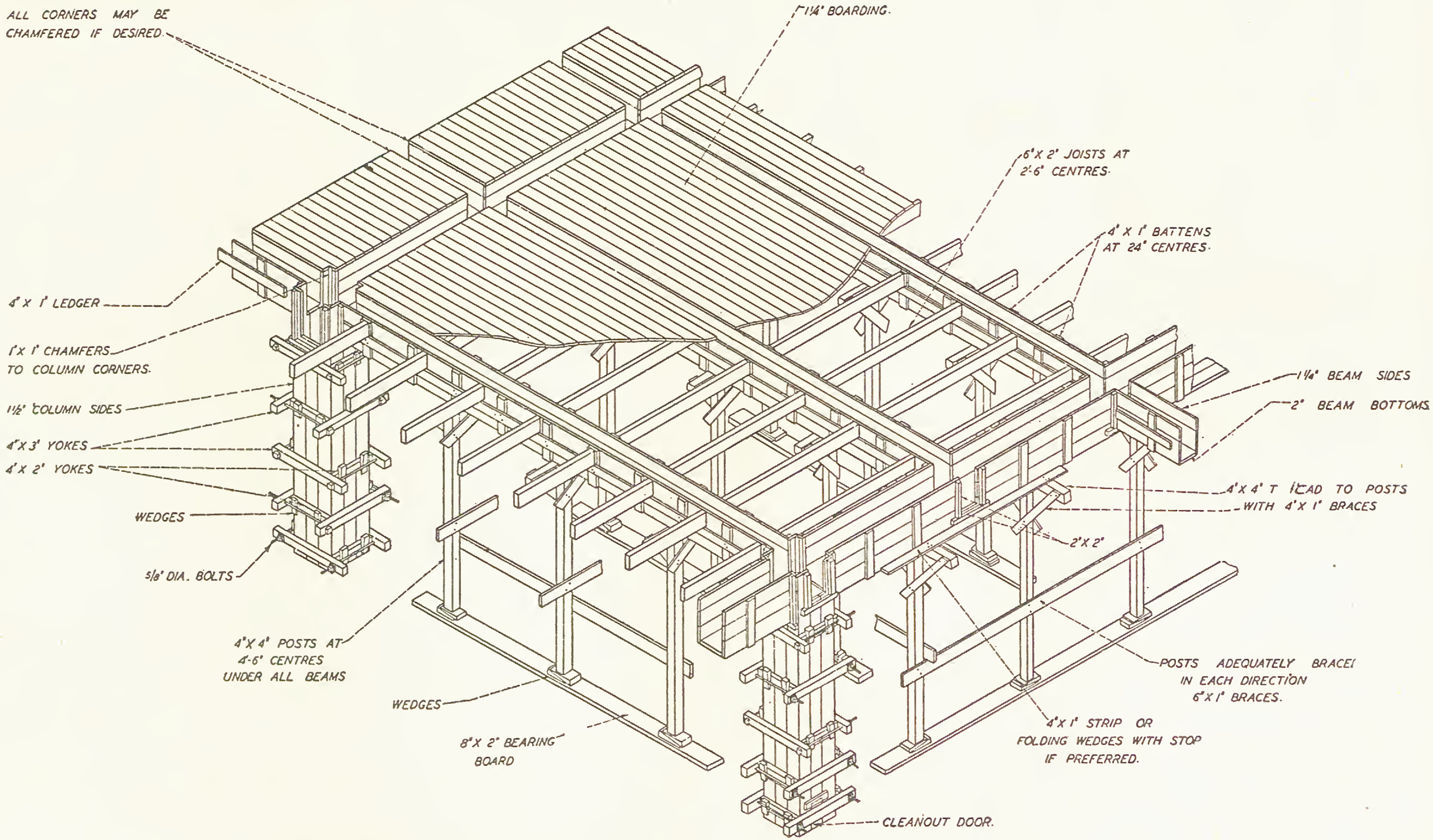


Fig. 18.—Formwork for reinforced concrete columns, beams, and floors—a typical example.

addition to its own weight, the incidental loads from the building operations above.

In a building of any size constructed entirely of reinforced concrete it is advisable to design the formwork in detail before the work is commenced so that use can be made of standard sizes of timber readily available, and so that these may be ordered in suitable lengths for the particular work for which they are intended and avoid any cutting to waste.

Columns.—Column forms should be wrought and thicknessed in order to ensure a fair face. As a general rule, three sides of a column form are built up in panels and assembled by means of surrounding yokes or clamps. The fourth side is left open to facilitate the placing of the reinforcement. This fourth side is formed by fixing on single boards as the concrete is placed in position, the boarding being kept a few inches ahead of the concreting throughout the operation. This permits of the concrete being thoroughly rammed and consolidated without difficulty. Typical arrangements of column forms are shown in Fig. 19, the dimensions given being suitable for columns of average size.

Octagonal columns may be dealt with in a similar way, but for circular columns it is generally found advisable to use narrow battens vertically and to make the whole form in two units or, what is more convenient, to use steel forms. These are rather expensive in first cost, but as column forms can be stripped very quickly, not many forms are required, and the amount of repetition possible makes the cost comparatively low when spread over a large number of columns.

Beams.—As a rule, for average-size beams 2-inch boarding is used for the soffits and $1\frac{1}{4}$ inches for the sides. Beam soffit forms should be given a camber of about $\frac{3}{8}$ inch per 20 feet of span to allow for the formwork settling down a little when the concrete is placed and still leave a slight camber when the work is completed.

A typical beam form is illustrated in Fig. 19, but this is amenable to revision and adjustment as necessary to suit local circumstances and the design of any particular job.

In every case beam forms should be arranged so that the sides may be removed without affecting the bottom boards and without interfering with the continuous temporary support of the props.

Walls.—Formwork for walls may be of many different types, but in general principle it consists either of an arrangement by means of which tying wires or bolts between two sets of face forms provide the necessary support, or alternatively an arrangement in which the two sets of face forms are independently supported by means of raking struts.

The former is much more economical whenever it can be adopted, but it has the defect that the ties pass through the concrete. Where wire is used for this purpose it is necessary to cut it back at not less than $\frac{3}{4}$ inch from the face of the concrete and stop up the hole. This must

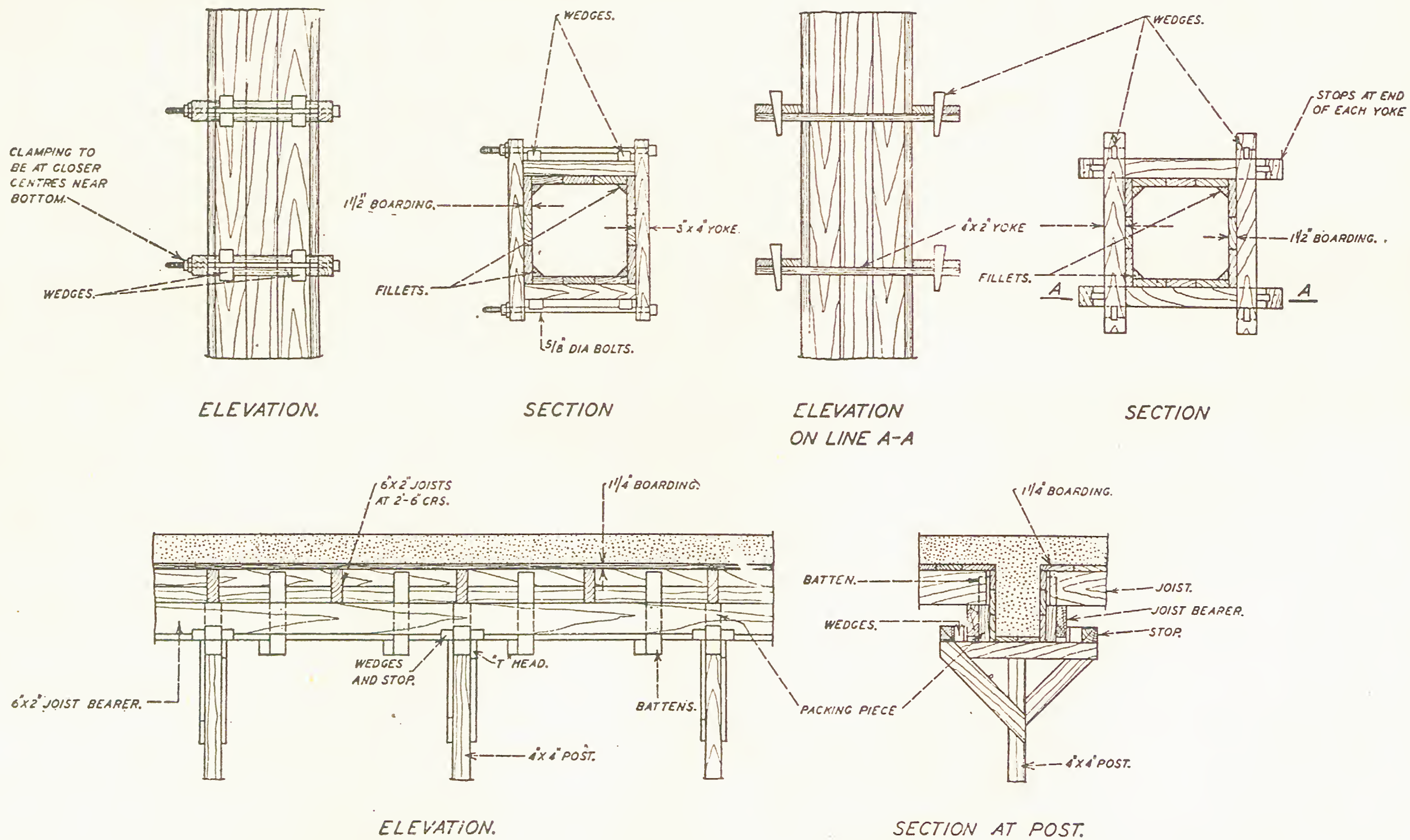


Fig. 19.—(*Top*) Typical formwork for R.C. columns. (*Bottom*) Typical formwork for R.C. beams

be done in order to prevent corrosion commencing at the ends of the exposed wires, but it will be appreciated that the effect of the patches on the surface of the concrete is not pleasing. Where bolts are used these are either placed through ferrules which are left in the work, or the bolts are well greased so that they may be tapped out of the concrete when the forms are removed. The ultimate result is more satisfactory and the effect a little more pleasing than when wire is adopted.

The chief danger in wall formwork is that of bursting out during concreting. This occasionally occurs at the bottom of the wall, and care should be taken to guard against it by strutting the formwork horizontally at the base of the wall.

In a long wall it is an advantage to make up the walls in panels which may be re-used several times. Such panels may be supported by posts or "soldiers" or may be wired together as described above, separators being used to maintain the correct thickness of the wall between the forms.

Bunkers.—The formwork of bunkers is usually carried out on similar lines to that described above, but it will be found that for the majority of sloping bottoms of bunkers it is necessary to board the upper surface of the slab, and this may also require to be weighted down to prevent bulging.

The formwork for bunker work is cut about to such an extent that it is seldom of further use, but where a bunker embodies several similar hoppers the formwork may be arranged in such a way that it can be re-used several times.

There are now on the market several different types of pressed-steel forms which may be used to advantage in various kinds of work, although not applicable to all. Steel forms, properly cleaned and oiled before use, give a better surface to the concrete than timber forms and they have a much longer life.

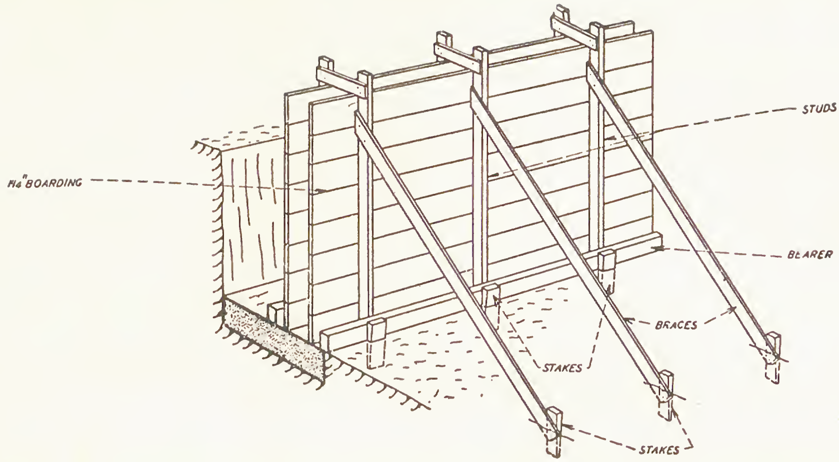
Preparation of Moulds.—It is of great importance that all forms for concrete work should be treated in some way before the concrete is placed so that the cement will not adhere to them. If this treatment is not given they will be difficult to remove and in some cases are likely to bring away with them portions of the concrete. The coatings generally used are:

Concrete mould oil (specially manufactured for the purpose).

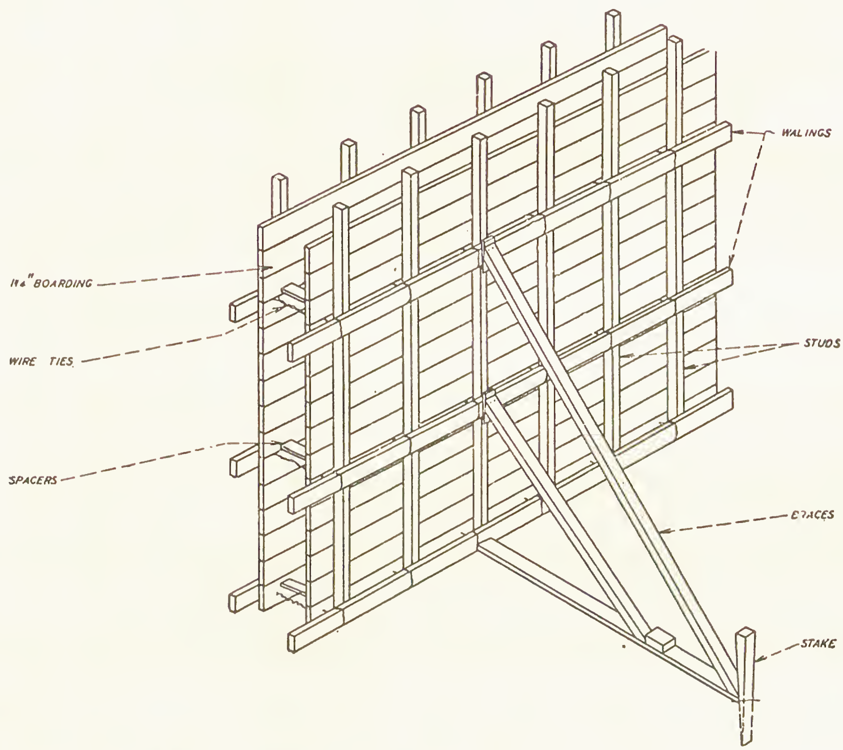
Creosote.

All these are quite satisfactory, although creosote tends to leave a dark stain on the concrete which may take some time to weather off. Creosote, however, has the advantage of acting as a preservative of the timber forms. It is an advantage and lengthens the life of the forms if they are given a coat of creosote when first assembled, and the coating should be repeated immediately before truing up and before concreting.

It is very important to avoid contamination of the reinforcement with the material used for preparing the formwork. Any such material



WALL FORMWORK FOR WALLS OF MODERATE HEIGHT



WALL FORMWORK FOR WALLS OF GREATER HEIGHT

Fig. 20.—Typical shuttering for walls.

left on the steel will completely destroy, over the area affected, the adhesion which is essential to the strength of the finished work.

Removal of Formwork.—It is of great importance that forms are not moved until the concrete has sufficiently matured to support its own weight without damage.

The following table gives the approximate minimum times for removing formwork from various concrete members when standard Portland

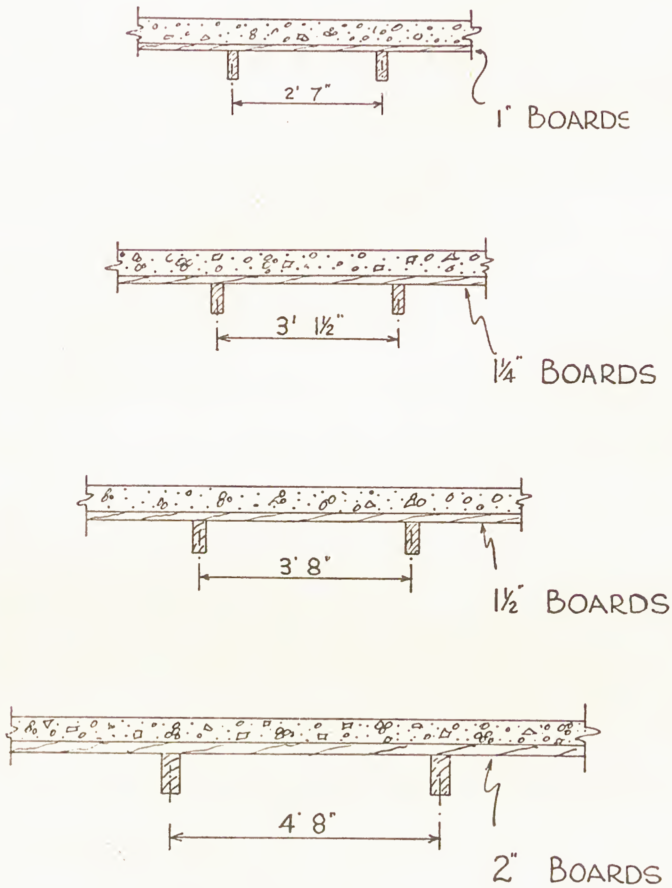


Fig. 21.—Shuttering or formwork for reinforced concrete slabs.

cement is used at normal atmospheric temperatures, it being assumed that the work will not be loaded for several days after the periods given.

Part of Structure.	Minimum Period before Striking Forms.
Vertical wall sides	4 days
Column boxes	4 ,,
Beam sides	4 ,,
Flat slab up to 3 feet span.	4 ,,
For every additional foot of span add 1 day.	
Beam bottoms and props up to 20 feet span	21 ,,
,, ,, ,, above 20 feet span	28 ,,

Cold or frosty weather arrests the setting of concrete and a close examination of the work should be made before stripping forms from concrete which has been placed or has set during a cold period. In any case a period equal to the length of the frost should be added to each of the above-named periods for striking. Before giving instructions for the removal of any forms the concrete should be tested with a hammer, which will usually indicate the hardness and extent of the setting by the ring which is produced when the concrete is struck.

The periods given above are based on the use of standard Portland cement. Where a rapid-hardening cement or an aluminous cement is used they may be reduced, but in such cases the recommendations of the makers should be invited and strictly followed.

MAXIMUM SPAN OF FLOOR SHEETING FOR VARIOUS THICKNESSES OF SLAB
(Live Load = 75 lb. per sq. foot).

Thickness of Slab.	Thickness of Sheathing.				Thickness of Slab.	Thickness of Sheathing.			
	1 inch.	1¼ inches.	1½ inches.	2 inches.		1 inch.	1¼ inches.	1½ inches.	2 inches.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
3	32½	39½	46	59	8	29	35	41½	53
4	31½	38	45	57½	9	28½	34½	41	52
5	31	37½	44	56	10	28	34	40	51½
6	30	36½	43	55	11	27½	33½	39½	50½
7	29½	36	42	54	12	27	33	39	50

MAXIMUM SPAN OF WALL SHEETING FOR VARIOUS HEIGHTS OF WALL
h = height of wall and d = thickness of sheeting

h/d	1 inch.	1¼ inches.	1½ inches.	2 inches.	h/d	1 inch.	1¼ inches.	1½ inches.	2 inches.
Feet.	Inches.	Inches.	Inches.	Inches.	Feet.	Inches.	Inches.	Inches.	Inches.
6	16	21	25½	35½	20	10	13½	16	23
8	14	18	22	31	22	10	13½	16	23
10	12½	17	21	28	24	10	13½	16	23
12	12	16	20	27½	26	9½	13	16	22
14	11½	15	18½	26	28	9½	12½	15½	21
16	11	14	17½	24	30	9	12	15	20½
18	10	13½	16½	23					

MAXIMUM SPAN OF COLUMN SHEETING FOR VARIOUS HEIGHTS OF COLUMN
h = height of column and d = thickness of sheeting

h/d	1 inch.	1¼ inches.	1½ inches.	2 inches.	h/d	1 inch.	1¼ inches.	1½ inches.	2 inches.
Feet.	Inches.	Inches.	Inches.	Inches.	Feet.	Inches.	Inches.	Inches.	Inches.
6	16	21	25½	33½	20	8½	11½	14	19½
8	14	18	22	31	22	8	11	13½	18½
10	12½	16	20	27½	24	8	10½	13	17½
12	11	14½	18	25	26	7½	10	12½	17
14	10½	13½	17	23	28	7½	9½	12	16½
16	9½	12½	15½	21½	30	7	9	11½	16
18	9	12	15	20½					

$w = 125$ (Tables from *The Concrete Year Book.*)

CHAPTER 3

FLOORS, JOINTS, AND PARTITIONS

TIMBER floors are a form of bridging consisting of timbers set on edge, known as *Joists*, carrying boarding known as *Floor Boarding*. The floor is described as *naked* before the boarding is laid, and in this condition it is generally left until all the rough work in construction of the carcase of the building is complete. On the underside of the floor joists wood laths are nailed by the plasterer, and on these the plaster is spread. It is advisable that the flooring should not be laid until the plastering is completed, though this is not always done.

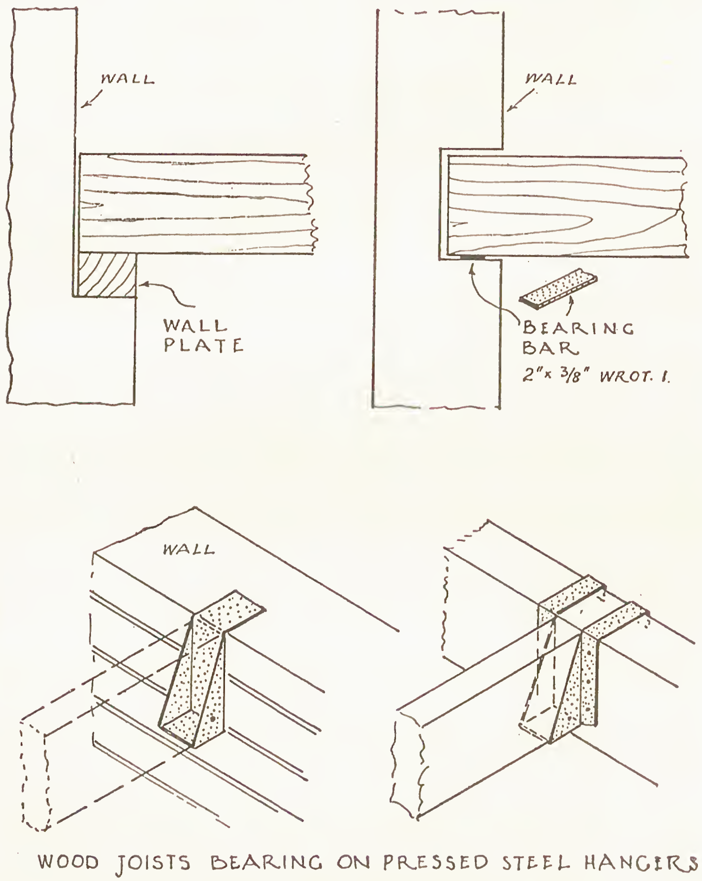


Fig. 22.—Methods of supporting ends of floor joists.

The joists above the top-floor rooms where the space above is not inhabited, and therefore not floored, are known as ceiling joists, and as they are not required to carry the same loads they are of smaller dimensions.

Classes of Floors.—Wood floors are of the following classes: *Single, Double,* and *Framed.* Ground floors of wood are sometimes constructed of joists laid direct on concrete, The practice, however, is not a good one, unless the space between the joists is very adequately ventilated. A

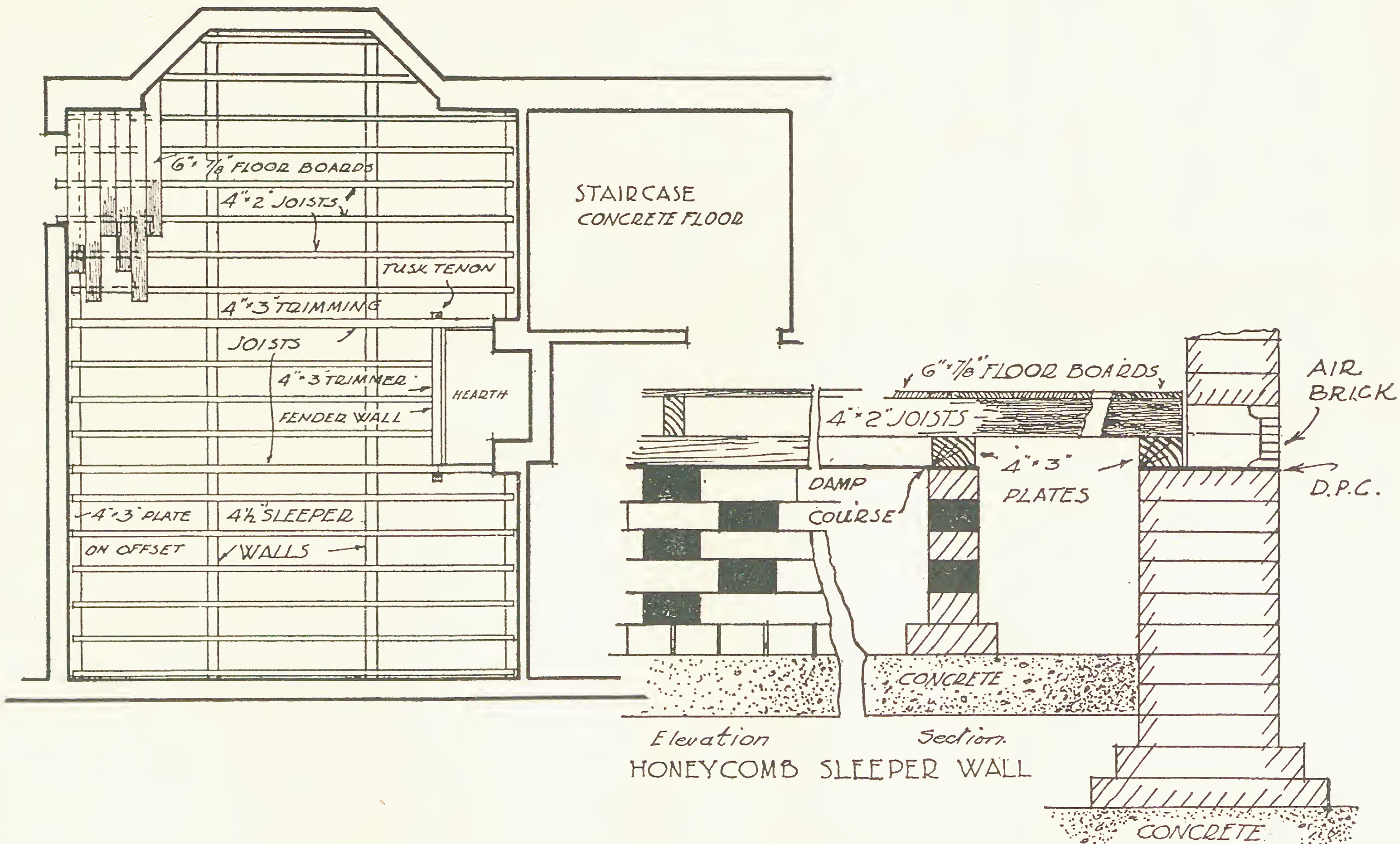


Fig. 23.—Single-floor details.

better method for such conditions is to lay the floor in wood blocks laid in mastic over the concrete. The blocks may be of northern pine 9 × 3 × 2 inches and the mastic is spread hot, directly over the surface of the concrete, which should be rendered level with Portland cement and sand in the proportions of 1 to 2.

Single Floors consist of bridging joists supported on the walls or frame of the building.

On ground floors they are usually supported on sleeper walls at intermediate points so that the effective span is reduced and joists of small section (3 × 2 inches and 4 × 2 inches) can be used. The joists are laid on edge, usually at centres of between 16 and 18 inches.

Sizes must comply with the by-laws (see table of sizes, pages 113–114).

The ends of floor joists are supported either directly on the walls or on bearing plates of wood or bearing bars of mild steel. But wood plates should not be built in the walls ; they should be placed on corbel brackets or on the sleeper walls.

Where the ends of joists rest on the outer or inner walls an open pocket should be left so that air can circulate around the joist ends. If joists are tightly built in they may be attacked by dry rot. Mild-steel bearing bars may be built in the wall to give a level bearing and to spread the load, but the bars should be protected from corrosion by rustproofing or coating with two coats of bitumen paint. If bearing bars are not used the joists must be packed at the bearings to level them. Pieces of slate are often used for this purpose, but this does not give a satisfactory bearing.

On the ground floors the joists must be laid at or above the level of the damp-proof course. They should be spaced at the specified centres, after the bearing bars have been levelled, and temporarily secured by nailing a few battens across.

Where the joists are supported on a cavity wall, the joist ends should not project into the cavity or they may become damp, or collect mortar droppings as the wall above is built up. An open gap should be left at the sides and top of each joist end for ventilation.

Strutting to Joists.—No joist should be less than 2 inches in breadth or the floor will be springy ; and to stiffen any joist over 8 feet in length *Herring-bone Strutting* is necessary. This consists of pairs of diagonal struts, usually 2 × 1 inch, with splayed ends skew-nailed to the joists.

Alternatively, solid strutting cut to make a tight fit between the joists can be used with a tie rod bolted at the ends (Fig. 24). Floor joists should be strutted when the span exceeds 8 feet. The *span*, it should be noted, is the distance over which the joist extends without support : and when joists do not rest on wall plates at both ends, but have to be cut to provide an opening such as that required for a staircase or for a fireplace, for example, the operation is called *Trimming*, and the joists are described as *Trimmed Joists*.

To carry the ends of the trimmed joist, a stouter joist is run in at right angles to them and extended between the last "not-cut" joists. These must also be of stouter dimensions, as they have to carry the additional

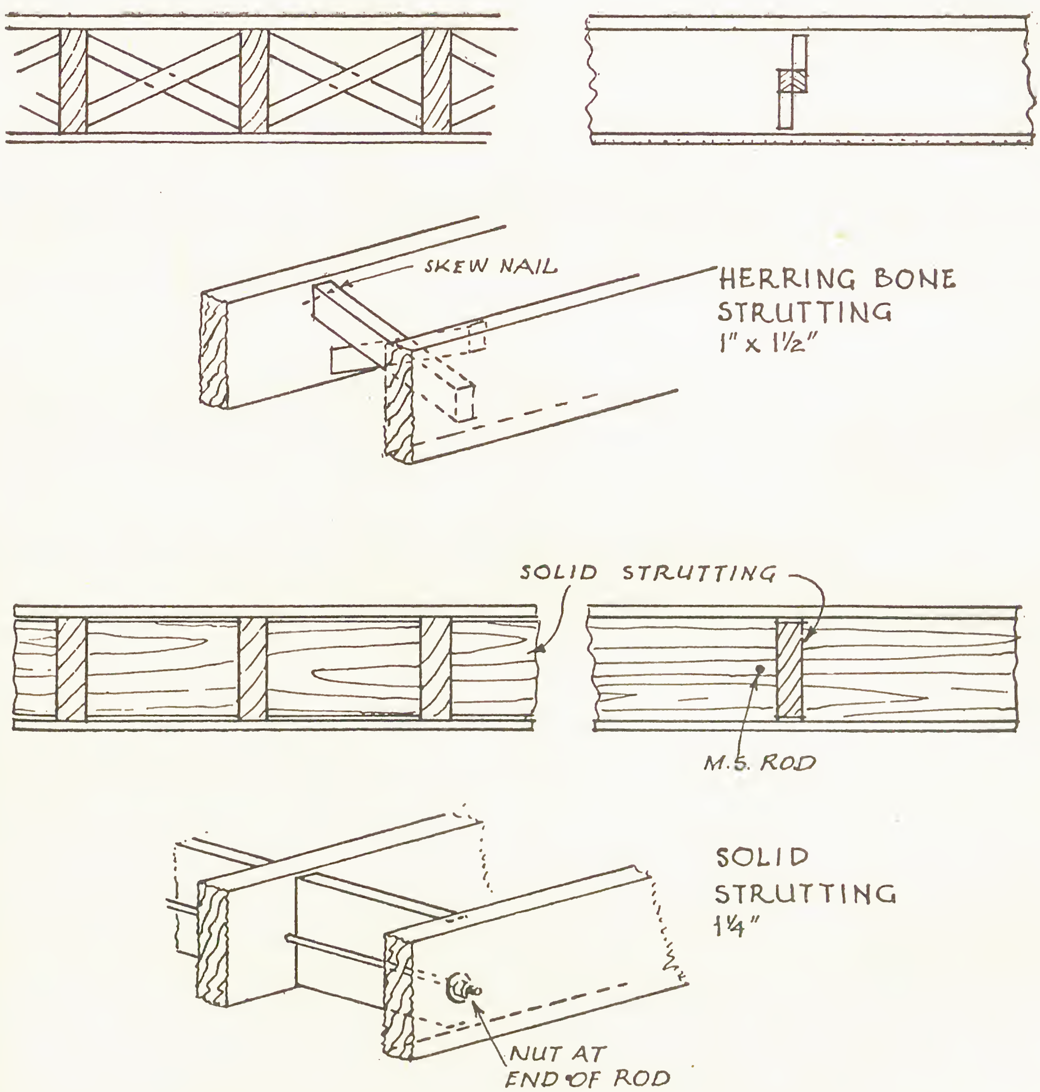


Fig. 24.—Methods of strutting floors to provide lateral stiffening.

weight of the trimmed joists, transmitted to them by the "trimmer," and are known as *Trimming Joists*.

Size of Trimming Joists.—The rule of thumb for arriving at the extra dimensions required in the trimming joist is to add $\frac{1}{8}$ inch in breadth to

the size of the common joists for every trimmed joist supported by the trimmer.

To afford support, additional to that given by the wall plate, to joists in a ground floor, brick walls built in honeycomb brickwork for ventilation and $4\frac{1}{2}$ inches thick are formed at distances not more than 6 feet apart and run at right angles to the joists.

On these walls are rested 4×3-inch plates and to them the joists are spiked. These walls are termed *Sleeper Walls*, and the plates *Sleeper Plates*.

In modern practice, timber plates are often omitted and galvanised-iron bearing bars used instead.

Timber plates should not be built into walls as they tend to rot in such positions.

Fender Walls are low walls of a similar nature built round a fireplace opening to carry the trimmed and trimmer joist to a ground floor.

Spikes.—The nails used for fixing the joists to plates are known as spikes, generally 5 inches long. *Round-wire Spikes* are *French Nails* circular or oval in section, and *Oval Wire Nails* up to 3 inches long are used for general fixing, their flat shape being less likely to cause splitting.

Corbel Pins.—The plates referred to above which carry the joists may be required to be supported away from the wall " for ventilation " or other purposes where they cannot be built in, such as into a chimney breast. This support is generally afforded by corbel courses built out from the face of the brickwork.

However, an alternative method is to build in corbel pins or brackets $3 \times \frac{3}{8}$ inch of wrought iron at distances 3 inches apart. These pins are split at the ends and turned upwards and downwards into the brick joints in the interior of the wall, and turned upwards 2 inches at their outer end to clamp the wall plate. This is a far better method of fixing a wall plate than building into the brickwork in any situation where damp is to be feared, as it affords a means of permitting air circulation round the ends of the floor joists as well as allowing the plate to be free of surrounding brickwork.

The joints used in forming floors are described later, but in passing it may be noted that the joints in the length of wall plates are usually nailed, but in better-class work either hardwood pins or two small bolts are used.

Bridging or Common Joists, in single floors, are usually laid with their centres 16 inches apart. This dimension has been accepted as that requisite to prevent any springiness in ordinary floor boards of 1 inch thickness.

As has been said, the joists are set on edge and laid across the shortest

span between the walls enclosing the room. At their ends they may bear on wall plates 4 × 3 inches, to which they are spiked through their sides, on galvanised iron bearing bars or direct on the brickwork.

Rule.—A rule of thumb for determining the depth of common joists is to take half the span in feet, add 2, and the result is the depth required for the joist in inches.

Thus: In a span of 12 feet, 6 being the half of 12, making 8 with 2 added, 8 inches is therefore the depth of the joist. But as 9 inches is the stock size that will be the depth of the timber used: any reduction in the square can be effected by using narrower width, though the minimum width of 2 inches for stability should be remembered.

In this matter it should be remembered that for the same cubic quantity of timber the deeper the joist can be made the stronger will be the floor, as it is in the direction of their depth, *i.e.* vertically downwards, that joists are weighted in a floor. It is also important to remember that joists to carry a ceiling should never be more than 3 inches wide, or they will be likely to cause cracks along their centres in the plaster work of the ceiling.

Joists Parallel to Walls must never be laid touching the wall, but should not be fixed at a greater distance than 2 inches from the wall.

The Timber to be used for the joists will be fir, specified in the following manner: "The whole of the fir timber to be of the best red fir from [port specified], sawn die square, and to hold to the scantlings [dimensions] specified. Provide and fix floor and ceiling joists of the dimensions figured with wall plates $4\frac{1}{2} \times 3$ inches under same."

Joists against Flues or chimney breasts should be kept at least 3 inches away from the brickwork, and no timber joist shall be fixed under any fireplace, nor any timber beam enter the brickwork or any chimney breast or flue.

Defects will be found specified as follows: "All timbers to be free from sap, shakes, large, loose or dead knots, wavy edges or other defects and properly seasoned."

Camber in Joists.—It is frequently found that long joists have a slight curve or camber in their length. This is due to the method of stacking during seasoning, and a joist so shaped should be placed in the job with the camber upwards. If one side of the timber is more knotty than the other, this side should also be kept uppermost, as when the joist is loaded the upper part of it is under a strain known as "compression," which tends to force the fibres together, so that in this position the knot-holes will be forced together rather than apart.

The Advantages of Single Floors are that for the expenditure of a given quantity of timber they form the strongest floor, and they are the simplest and cheapest form of construction. They also lie in the whole

of the walls on which they rest and the load they carry is distributed equally on these walls.

Disadvantages.—There comes a point, however, when the span is too great for a single floor, as the depths of the joist required, from the rule given, would be too great and be of themselves too great a weight

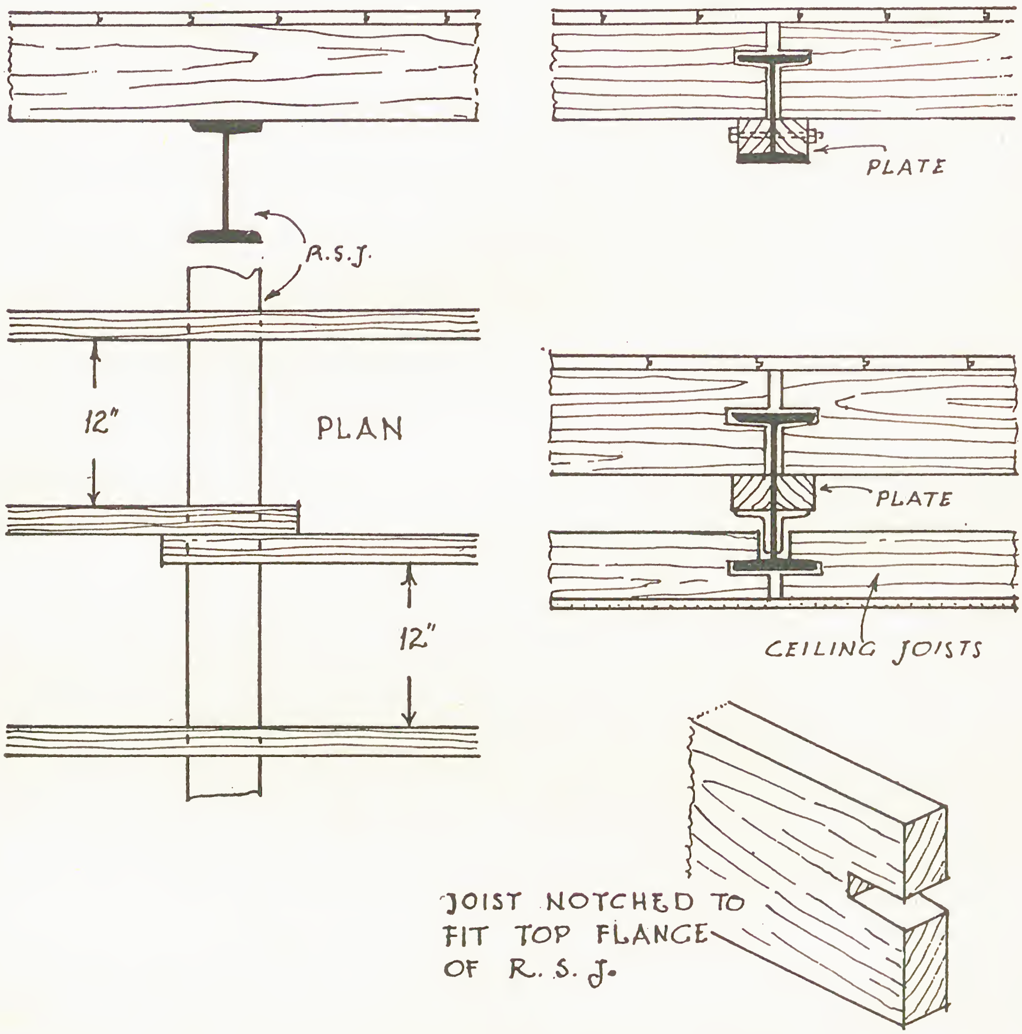


Fig. 25.—Details of double floors showing how floor joists are supported on R.S. beams.

for the stability of the walls. Another disadvantage of the single floor is that the joists require a good deal of trimming unless they are to rest equally on the wall over openings over bay windows, doors, and ordinary windows when wide: also they require wall plates, often built in, along the whole length of the two longest sides.

Double Floors.—Where the shortest distance between the walls

bounding an area to be floored is too great, *i.e.* over 12 feet, to permit of the use of common joists unsupported in the span, heavier timbers known as *Binders* are placed across this shortest span, and the common joists are then run over these and at right angles to them.

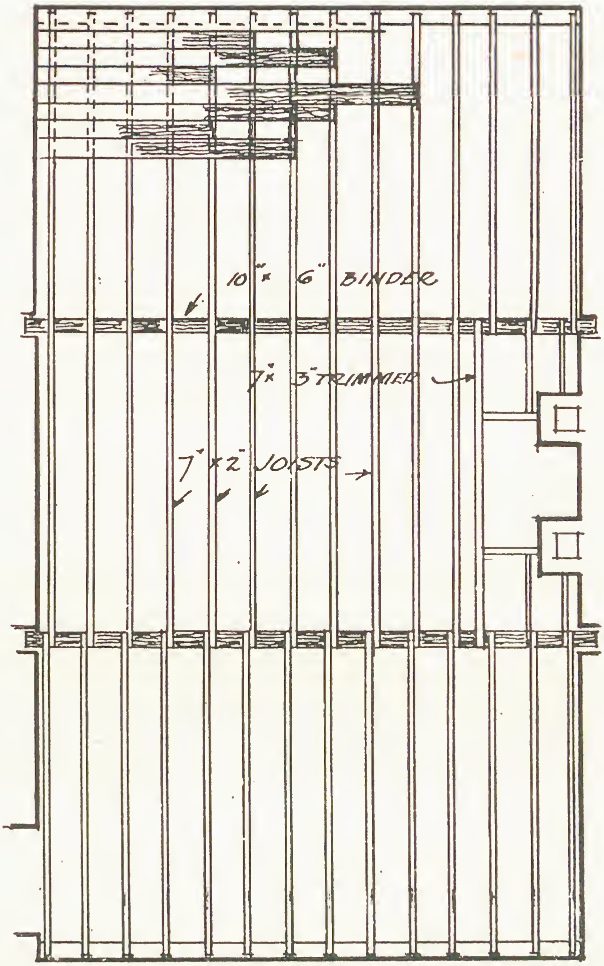


Fig. 26.—A double floor.

The span between the binders should not be more than 6 feet, having due regard to the walls on which they rest. That is to say, that it will be better construction to make this span more than 6 feet than to slavishly adhere to this rule and in so doing cause the binder to come above window or other openings in the wall. They should instead rest on the solid masonry piers between openings. The space between two binders is called a *Case Bay*, and where there are three or more bays, the space between binder and wall is termed a *Tail Bay*.

The dimensions recommended by Tredgold for binders in Baltic fir are given in the following table, all the binders being assumed to be fixed 6 feet apart:

Length of bearing in feet	Breadth in inches.									
	Depth 6 inches.	Depth 7 inches.	Depth 8 inches.	Depth 9 inches.	Depth 10 inches.	Depth 11 inches.	Depth 12 inches.	Depth 13 inches.	Depth 14 inches.	Depth 15 inches
5	$4\frac{3}{4}$	3	2	—	—	—	—	—	—	—
6	$6\frac{3}{4}$	4	3	2	—	—	—	—	—	—
7	—	$5\frac{1}{2}$	4	$2\frac{3}{4}$	2	—	—	—	—	—
8	—	7	5	$3\frac{3}{4}$	$2\frac{3}{4}$	2	—	—	—	—
10	—	—	8	$5\frac{1}{2}$	4	3	$2\frac{1}{2}$	—	—	—
12	—	—	—	8	6	$4\frac{1}{2}$	$3\frac{1}{2}$	—	—	—
14	—	—	—	—	8	$5\frac{3}{4}$	$4\frac{1}{2}$	—	—	—
16	—	—	—	—	$10\frac{1}{4}$	$7\frac{3}{4}$	6	$4\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{1}{4}$
18	—	—	—	—	—	10	$7\frac{1}{2}$	$5\frac{3}{4}$	$4\frac{3}{4}$	4
20	—	—	—	—	—	—	$9\frac{1}{2}$	$7\frac{1}{4}$	6	$4\frac{3}{4}$

Templates.—The ends of the binders should rest on stone templates to distribute the weight, and between the stone and the wood there should be a lead pad to exclude damp from the timber. It will be preferable if these templates be formed into corbels, as, the timber in a binder being of

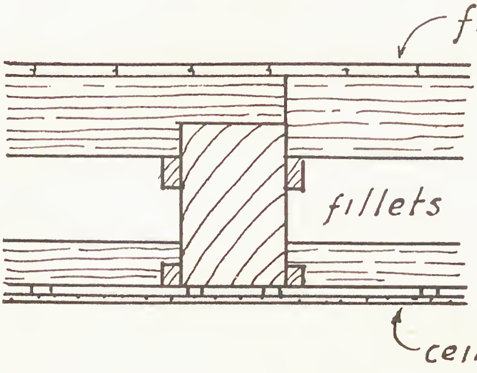


Fig. 27.—Details of section through double floor.

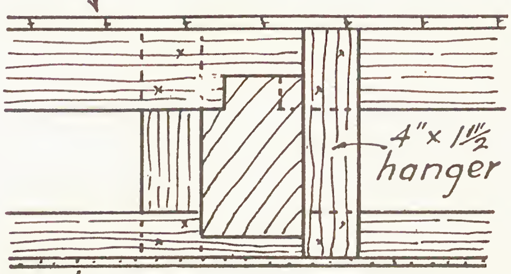


Fig. 28.—Chase mortise used in double floor.

larger dimensions than that of a joist, it is more than ever essential that it should not be entirely surrounded with brickwork or masonry.

Cast-iron Shoes for the ends of binders are used alternatively, and are specially adapted for use in party walls, the bye-laws in connection with which require a minimum thickness of brickwork to be left in the centre of the party wall and between the ends of any timber. These shoes form an additional protection against fire, and being $6\frac{3}{4}$ inches in their bottom portions also afford an additional bearing surface, in the nature of a corbel to the binder. To build these cast-iron shoes into brickwalling, their width dimension being 9 inches at least, it is necessary to build in $18 \times 4\frac{1}{2} \times 3$-inch stone lintels over them.

Joists and Binders.—The floor joists are jointed to the binders by joints termed "Cogged Joints" (see definitions).

Ceiling Joists.—In double floors of the usual type the ceiling is carried by a second set of common joists known as *Ceiling Joists.* These are of fir 4×2 inches, and are fixed to the binder by means of a notch being cut in their ends and fitted over a $1\frac{1}{2} \times 1$-inch fillet nailed flatways on to the side of the binder flush with its bottom face. The name given to this fillet is the *Forking Fillet.*

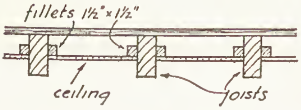


Fig. 29.—Open ceiling formation.

Open Ceilings.—Where it is desired to show the joists, an extra series of ceiling joists as above referred to will not be required. The simplest form of construction adopted in these circumstances is to nail 2×1-inch fillets on the sides of the ordinary joists to lath to and to plaster over these. The binders are thus exposed as beams if of suitable timber, or they may be boxed in with a boxing of any timber desired.

Ceilings Panelled in Plaster.—Where a double floor is required to carry a ceiling of plaster panels, the underside of the ordinary joists are lathed and plastered, and a " cradling " or " firring " of timber is framed round the binders, and these lathed and plastered over also. Plaster mouldings may be run in the angles of the divisions so formed between the binders.

Plaster and Wall Board.—Alternatively plaster board or wall board may be fixed to the underside of the ordinary joists and ceiling joists thus be saved. In some ways this method is preferable to any, as plaster when fixed to timbers having the grain running in different directions is very liable to crack, to which defect the wall board is not liable.

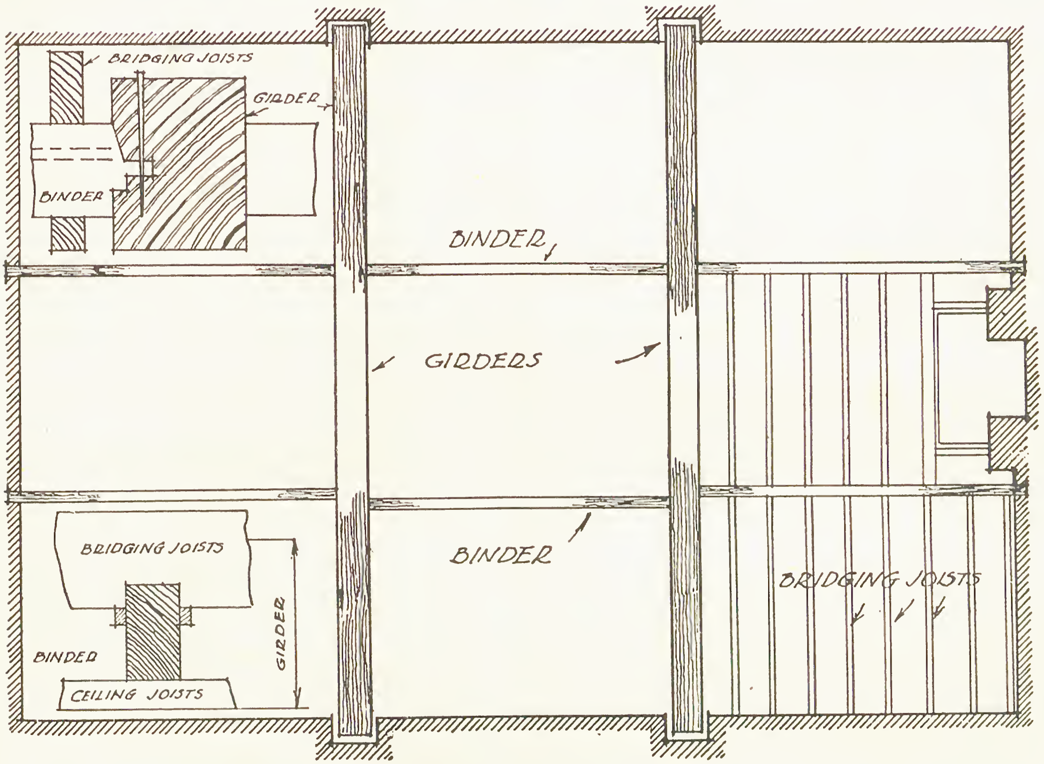


Fig. 30.—Framed floor details.

The Advantages of Double Floors are that they are not so liable to the transmission of noise, and that the plaster ceilings are not so liable to crack, *i.e.* when the plaster is run over ceiling joists. By placing additional binders close to the walls, it is not necessary to rest the ordinary joists on the walls, which is a great advantage in the matter of the protection of these timbers from decay caused by damp.

Disadvantages.—The method of cutting the timbers, however, is not ideal, and the unequal loading of the walls, at the points where the binders rest on them, being unequal may be a serious disadvantage.

Framed Floors.—This type of floor is used mainly in factories and

buildings in which large areas are required to be floored and where the span is too great, even in its shortest dimensions, for binders only to be used unsupported. Consequently, to give additional support to the binders, larger timbers known as *Girders* are laid across the shortest span, and the binders are laid at right angles to these.

The girders rest on stone templates in a similar manner to that employed with the binders in double floors, and the binders are framed into the sides of the girders by means of a joint known as a *Double-tusk Tenon.* But as this joint necessitates the cutting away of a considerable amount of the timber of the girder, the binders should not be run in a continuous line so as to bring the tusk tenons opposite, but they should be staggered.

As an Alternative Method of affording support to the binders from the girders, *Cast-iron Stirrups* are bolted to the sides of the girder shaped to fit the end of the binder. This does not weaken the girder, as it renders any cutting for the joint mentioned above unnecessary.

A Cheaper Form of framed floor, used particularly in Scotland, is one in which the binders are omitted, and the girders are placed closer together, when smaller-dimensioned timbers are made possible. The bridging joists are notched on to the girder with a shouldered notch, and the ceiling joists are hung by wood or metal straps to the bridging or common joists. An additional advantage in this type of framed floor is that it separates the floor from the ceiling, and thus renders sound less liable to transmission.

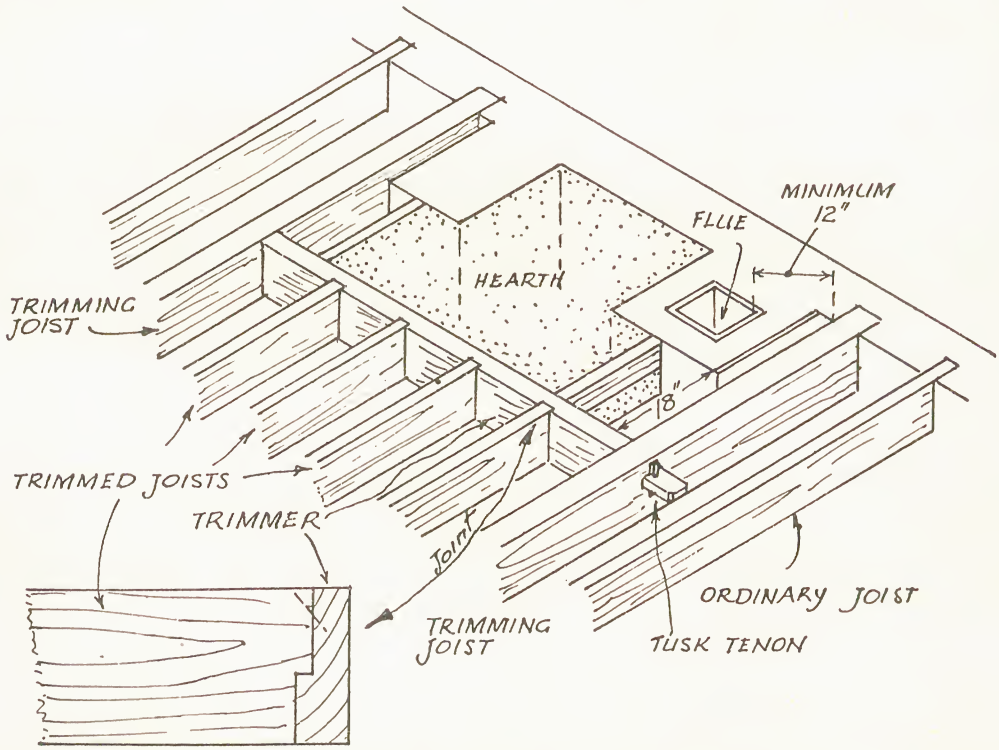


Fig. 31.—Trimming round upstairs fireplace.

In this connection, when hanging the ceiling joists, though it applies equally in a form of composite floor, it should be noted that the ceiling joists should be hung slightly higher in the centre of the room than at the side to allow for the settlement of the floor.

Girders.—It may happen that the span is too great for the economic use of timber girders—the dimensions required mathematically being too large for practical purpose, the timber required being too bulky, heavy, and altogether incommodious. In such circumstances the same required strength is obtained by the use of rolled-steel joists of considerably less bulk, or alternatively the girders may be built up in wood, or as a third alternative, trussed wood girders may be used.

Rolled-steel Girders are combined with wood floors in the following manner. Plates are bolted through the flange of the rolled-steel joist and rested on the upper face of the bottom flange on both sides, and the bridging joists are notched out to rest on these and nailed thereto. The ceiling joists are let into the underside of the bridging joists and run at right angles to them. In this method the steel joist is contained within the thickness of the floor.

Where the depth of steel joist required is too great to permit of its being contained within the thickness of the floor, the binders, instead of the bridging joists, are rested on the plates laid on the bottom flange, and the ends of these binders are strapped with metal straps screwed in to their sides and fitted with an adjustable nut and screw bolt passed through the flange of the steel joist. The ceiling joists are let into the underside of the binders in this form of combination-framed floor. That part of the steel joist which extends below the level of the ceiling is firred round or sheeted with expanded metal lathing to take the plaster, which then appears in the nature of a plastered beam projecting below the ceiling.

An Alternative Form of combination-framed floor construction is that in which the binders are rested on the bottom flange of the steel joist and bolted thereto with metal right-angle brackets; the ceiling joists and bridging joists being let into the binders and run across them at right angles. This method is more economical of timber and fixing.

Built-up Timber Girders.—The following forms for built-up timber girders, in substitution for solid girders of too large dimensions, are given by Tredgold.

Joggled or Keyed Beam.—This consists of two pieces of timber bolted together, side by side, and having hardwood keys let into grooves cut on their inner faces to resist any sliding tendency and render the two halves of the beams more rigid. These hardwood keys have their grain at right angles to that of the beam timbers.

An Indented Beam is one in which the upper layer of the composite beam is made in two pieces, having a King bolt at the centre of wedge-shaped pattern with its thin end downwards, so that when this is screwed up, the wedge-shaped bolt exerts a pressure similar to that of the keystone in an arch. The halves of the timber beam, which is built up of two layers,

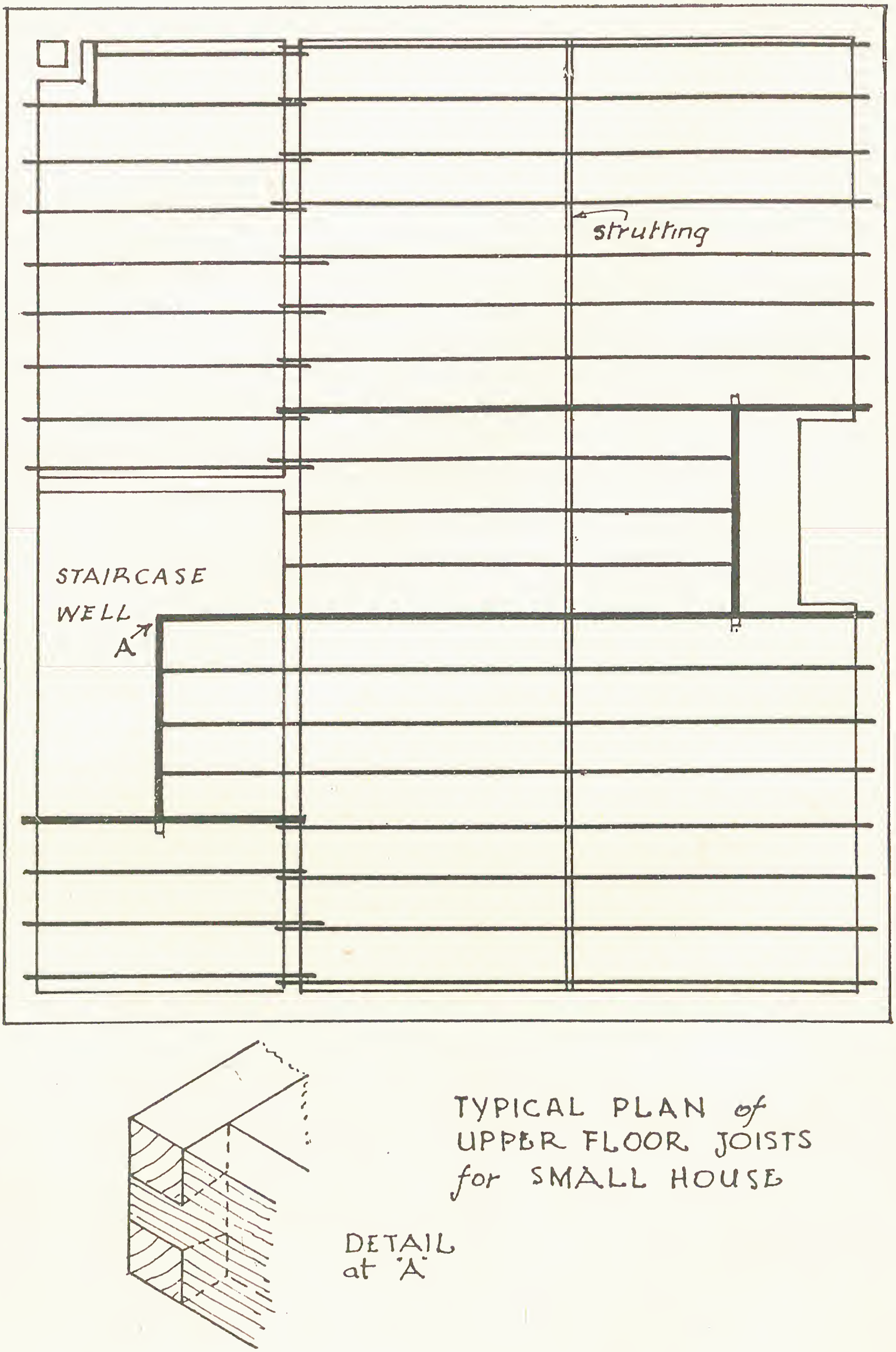

strutting
STAIRCASE
WELL
A
TYPICAL PLAN of
UPPER FLOOR JOISTS
for SMALL HOUSE
DETAIL
at "A"

Fig. 32.

the one *over* the other, are jointed with indents instead of keys to prevent sliding.

Tredgold's Rule in the matter of these indents and keys is that their

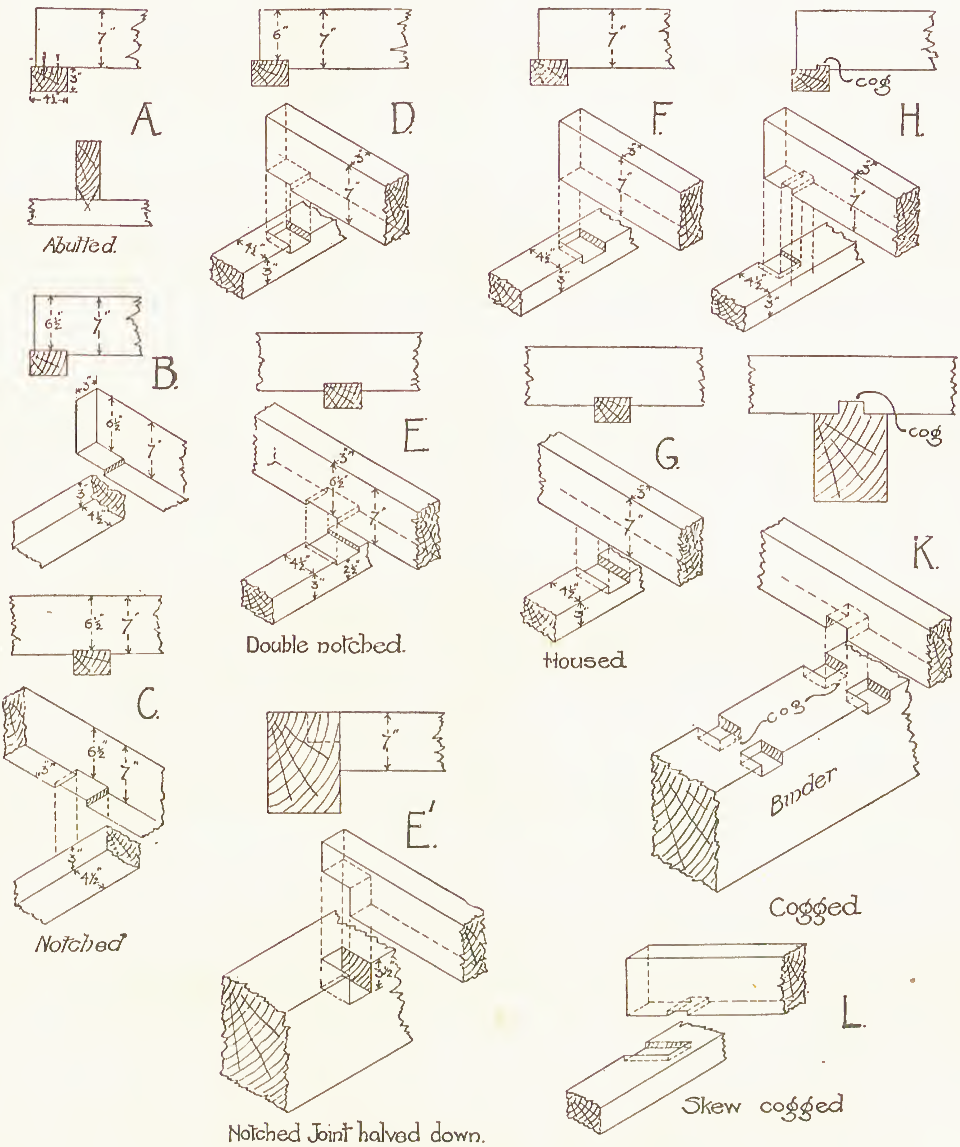


Fig. 33.—Methods of jointing plates and joists.

depth added together should not be more than one and a third of the whole depth of the beam, and the breadth of each about twice the depth.

The depth of all indents together should equal two-thirds the depth of the beam.

Trussed Girders are described in *Rivington* as follows, but it should be

noted that these, and the built-up wood girders last described, have been for the most part replaced by steel in modern times.

Wood beams may be strengthened by being cut down their length into two halves, and placing them together again with one of the halves reversed, end for end. They are then bolted together with the sawn faces outwards, small strips of wood being inserted between them to permit of the entrance of air. By this means the seasoning is more complete, and the reversal of the grain makes the beam of equal strength throughout its length. The two halves are termed *Flitches.*

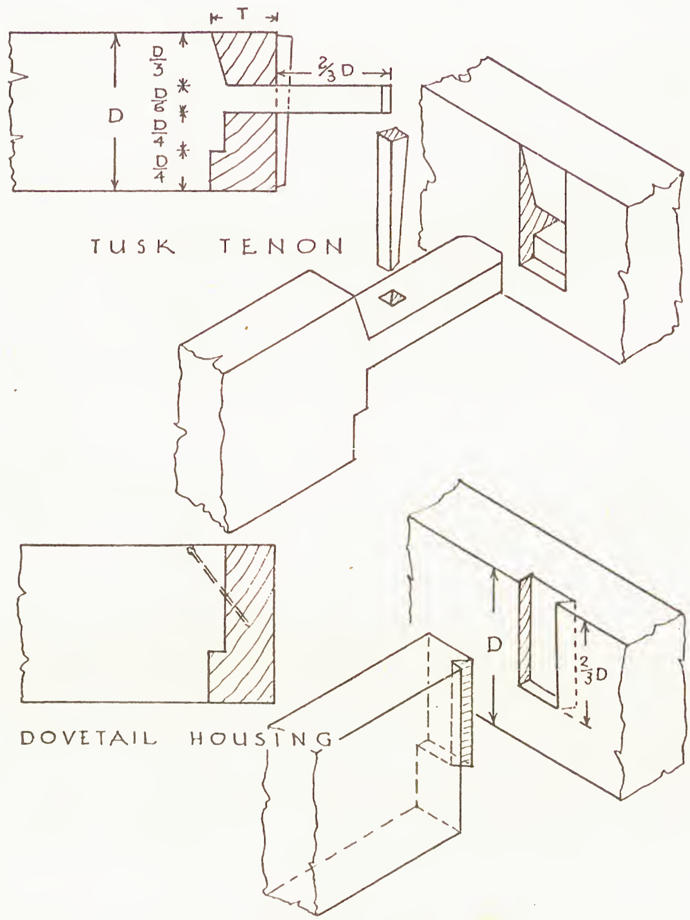


Fig. 34.---(*Top*) Tusk tenon used to join trimmer joists and trimming joist. (*Bottom*) Dovetail housing---a simpler joint used for joining ordinary joists to trimmer joist.

To increase the strength of a flitched beam, a flat iron plate is inserted between the reversed halves, and the whole is then bolted through with the bolts staggered.

An adaptation or modification of this is a composite beam in which the plate is replaced by two cast-iron struts, and running along the bottom of the beam a tension plate supported by a King bolt at the centre and similar bolts at each end.

Several varieties of the above are given in *Rivington,* including Queen-bolt trussed beams, beams trussed with tension rods, and deep trussing, the last of which is still to be seen in the construction of gantries. The reader is referred to this description for further information on this subject if desired.

However, it will be seen that the amount of work and the time necessary to be spent in these forms of construction render them far less economic than the use of rolled-steel joists.

DEFINITIONS, JOINTS, AND DETAILS

Satisfaction in the carpenter's work depends so largely on the proper use and construction of the joints, that it is thought advisable to deal with these separately and in detail, combining the explanations with definitions of the terms used.

Joints.—The joints used may be divided into three classes determined by their uses: that is to say:

(1) *Longitudinal Joints* are those used in lengthening timbers, such as may be subjected to compression, which is a pushing together, or a tensile strain, which is a pulling apart, or a bending strain, which term is self-explanatory.

(2) *Bearing Joints* are those specially devised for timbers subjected to bending strain either upwards, downwards, or sideways.

(3) *Framing Joints* are designed to resist shear, which is a tearing strain, in all kinds of vertical framing.

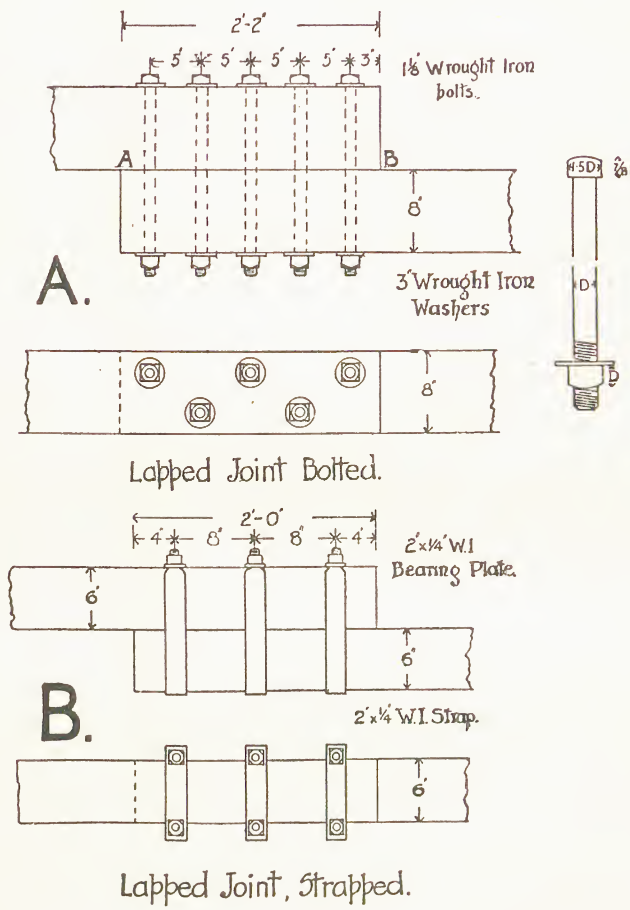


Fig. 35.

Longitudinal Joints.—The formation of the joints used in lengthening timbers naturally depends on the purpose to which the timbers are to be put and the strain to which they are to be subjected in consequence. The simplest form of lengthening timbers is to tie their ends together, side by side, with metal straps. This method is termed *Lapping*, and is suitable for either timbers in compression or in tension, though for the latter it is preferable if bolts are substituted for the straps.

Another elementary method of jointing timbers in their length is to butt the ends, which must be cut truly square, and to bind the ends of both timbers with plates of wood or metal. Such a method is termed the *Fished Joint*, and the plates are called *Fish Pieces* or *Fish Plates*.

The fish plates may be laid plain on the sides of the timbers and bolted, the bolts being staggered so as not to exert the strain on the same fibres.

In *Tension* such bolts would be more likely to crush the fibres ; consequently, to aid them, transverse grooves are cut in the timbers, and these are either filled with wood keys or with a thicker part of the fish plate. The first method is called a *Keyed Fished Joint*, and the second a *Tabled Fished Joint*. The cutting for either of these methods is not very considerable, as the keys do not require to be more than 2 inches square at the most, and rarely that, whilst the sinking for the tabling would seldom be required deeper than 1 inch ; but as the groove for tabling is much wider than for the key, this results in considerably more of the timber having to be cut away.

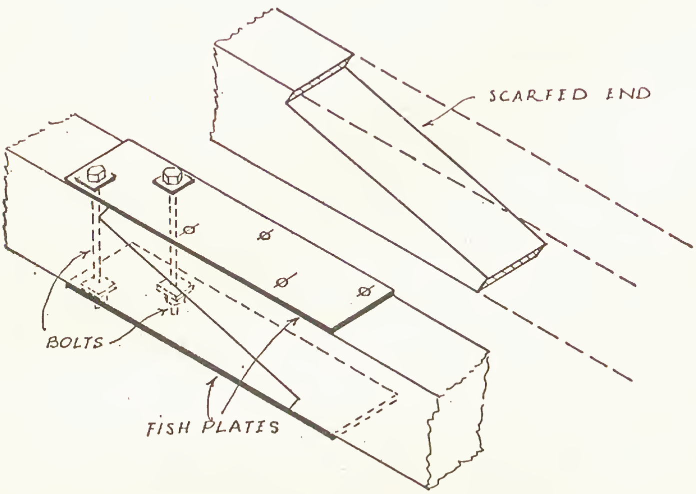


Fig. 36.—Scarfed joint with fish plates and bolts.

The Scarfed Joint.—Timbers are also jointed in their length by means of a joint known as the *Scarf*, which is, in its various forms, a kind of tabling cut on both timbers alike.

For Timbers in Compression, the scarfed joint is simply halving in the length of the timbers. The point which is important in jointing timbers in compression is to ensure as large bearing surfaces of one timber on the other as possible; and in halving, the two bearing surfaces together equal the whole area of the section of the timbers, and they are at right angles to the strain.

The halved timbers are bound at their sides with fish plates bolted through at right angles to the halved joint, and the bolts should be staggered as before.

Such a joint, however, would be useless for timbers subjected to pulling-apart strain, or *Tension* as it is termed ; as they would have to depend entirely on the bolts to resist this strain. Consequently, the halving is cut on the splay with a shoulder at each end and two shoulders at the centre spaced a slight distance apart to permit wedged keys being driven in. These tighten the joint, which is then fished as before with either wood or iron plates and bolted.

Timbers may, in certain conditions, such as tie-beams which are also weighted, be subjected to tension and compression, and the form of joint then used is a combination of the halved scarf and a hooked

shoulder joint tightened with a key or wedges at its centre. This joint may be formed with or without fish plates. Another form of the same joint is that which is halved simply without tabling, but in which two grooves are cut for hardwood wedges.

Where a timber is weighted at a certain point and, consequently, subjected to a strain across its length, a fish plate is bolted on to that side opposite to the direction from which the strain arises. A scarfed joint to resist this strain has the halving cut on the splay, and the shoulder on the side on which the pressure is exerted is cut at right angles to the length of the timbers, whilst that on the other side, the fibres of which are in tension, is cut at an angle. The fish plate on that side, by virtue of its own rigidity and the bolts holding it to the timber, assists in resisting the tension.

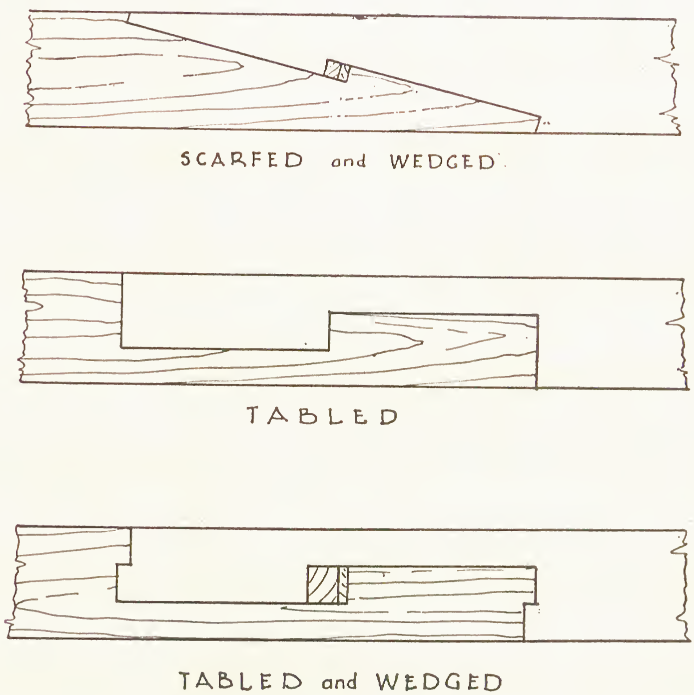


Fig. 37.—Joints to resist tension.

TRANSVERSE OR BEARING JOINTS

These consist of halving, notching, cogging, housing, and certain forms of tenoning; all of which are used in some connection in floor construction.

Halving is a self-explanatory term, and consists in cutting away equal halves of portions of two timbers in order that they may be joined together to form a joint of the same thickness as that of one of the timbers. The halving may be lengthwise, though it is also termed scarfing then, or it may be at right angles as when used to joint two wall plates at an external angle of a building.

When two wall plates are joined, one being on an external wall and the other on an interior or cross wall, the halving is cut at an angle or splayed to give some resistance to any tensional stress that may be set up when the plate on the cross wall is weighted. This is called a *Bevelled Halving*.

A Dovetailed Halving is one in which the tongue left on the upper

timber is cut in a dovetail or wedge shape to resist pull or tension. It is not a very suitable joint for wall plates at right angles, though it is sometimes so used; the objection to its use in carpentry being that in big timbers used at right angles, the shrinkage is likely to be unequal. A more suitable form for this joint when used for joining wall plates at right angles is that known as the *Dovetail Notch,* which has one side cut square and the other bevelled or dovetailed. This enables a wedge to be driven in on the square side and the two bevelled faces pushed tight.

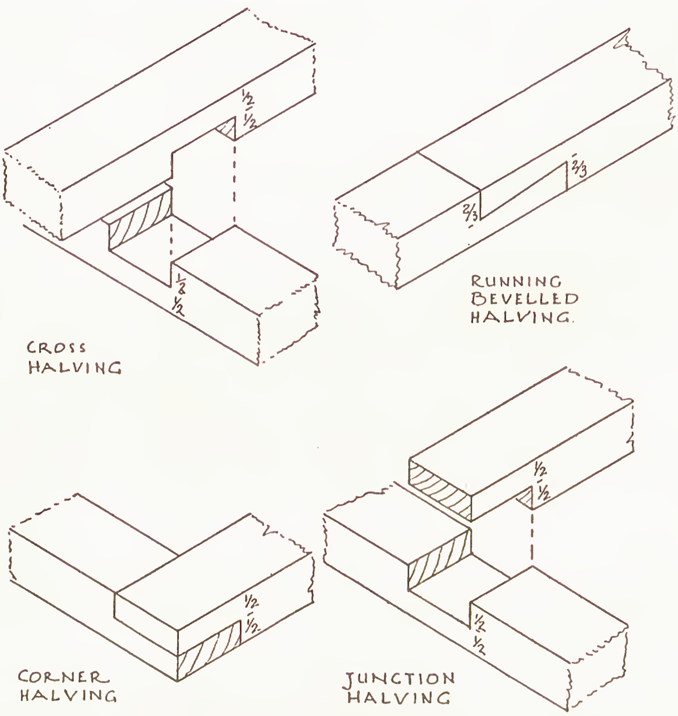


Fig. 38.—Halved joints.

Notching is mostly seen in floors in the joints between rafters and the timbers on which they rest at their ends or cross in their length. It is also a method of reducing the tops of joists of unequal depth to the same height. When the amount which the timber is required to be lowered is so great that it would necessitate cutting more from one timber than the requirements of strength would permit, the notch is cut on both timbers and the depth by this means is halved. This is called *Double Notching.*

Another form of *Notch* is known as a *Bird's-mouth Joint* and this is used on rafters to afford a fixing to a wall plate and also on rafters when passing ridge timbers and purlins.

Cogging may be considered as an improved form of notching, the notch on the lower timber being cut with a piece left to afford resistance to tension. Joists are cogged to on wall plates in certain conditions and also on to binders and to the plates on rolled-steel binders.

The advantages of cogging over notching is that it results in a stronger formation, as the timbers are not so much cut away, and the form prevents the timbers from pulling apart due to the *cog* left on the lower timber.

Tenoning.—A form of bearing joint used in the building of floor timbers is that known as the *Tusk Tenon.* This is used in jointing the trimmer to

the trimming joists, also in joining a joist framed into a girder. It is a joint specially designed to resist tension and to afford a bearing as deep as possible without weakening the timber in which the mortise is cut. The *Mortise and Tenon Joint*, it may be noted in passing, consists of a rectangular hole, *i.e.* the *mortise* cut in one timber and the *tenon*, a tongue the thickness of a third of the timber, cut to fit into the mortise. The sides of the mortise are termed the *cheeks*, and the surfaces on the other timber at the sides of the tenon are called the *shoulders*. A tenon is sometimes pinned through, and for this purpose a *pinhole* is bored through the mortised timbers and the tenon at a distance of one-third the length of the tenon. The tenon should be made shorter than the mortise, to give a good fit to the joint at the shoulders of the tenon.

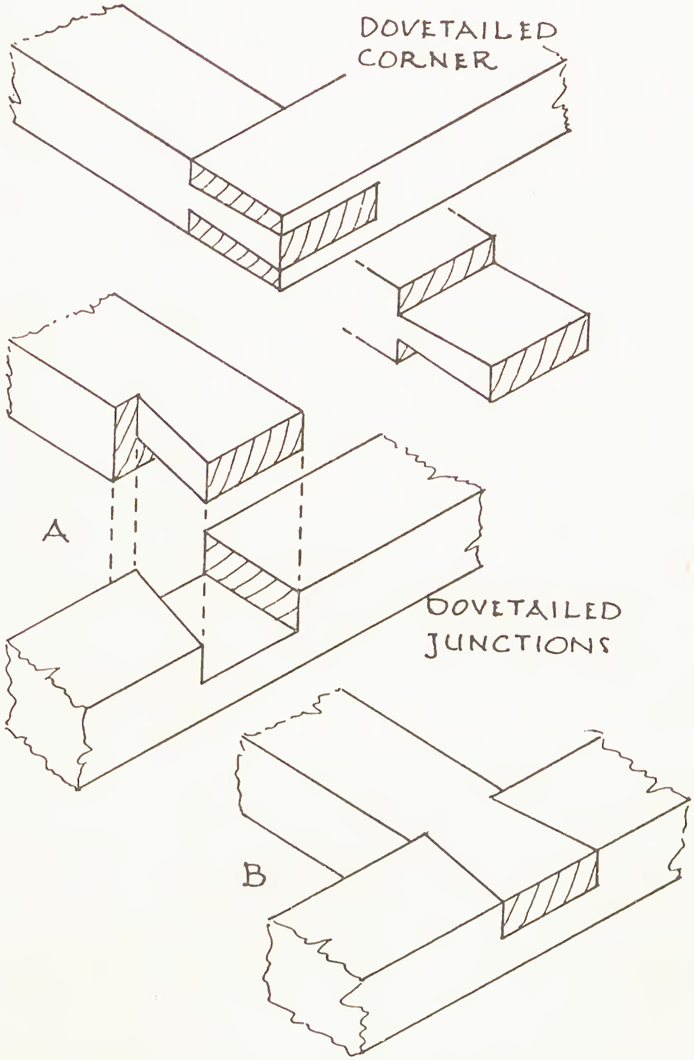


Fig. 39.—Corner and junction dovetail joints.

In the *Tusk Tenon* the tenon, which should be cut above the centre line of the timber it is let into, may penetrate and pass through the other timber, in which event it is pinned or wedged through a hole in its end; or, when the timber mortised is too big, the tenon terminates within the timber and is pinned through the top of the larger timber. The joist derives its name from the secondary shoulder or *tusk* which is cut below the tenon for the purpose, as has been said, of increasing the bearing. That

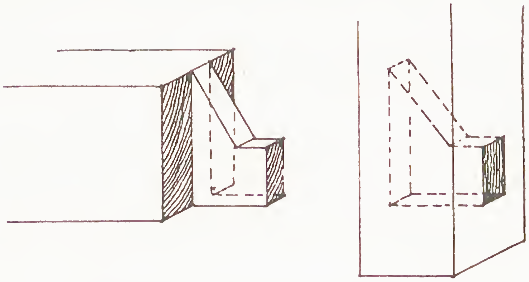


Fig. 40.—Haunched tenon.

portion above the tenon cut on the splay is termed the *Horn*, the splay being cut back from a point vertically above the upper corner of the larger timber in which the tenon is cut. The thickness of the tenon is one-sixth of the depth of the joist, and in width it is that of the joist. The projection given beyond the other timber should be about 3 inches, and the depth of the tusk is equal to that of the portion below it extending to the bottom of the joist. The dimensions of the parts of this joint have all been worked out mathematically by Tredgold, but the actual proportions in practical work depend to an extent upon the relative sizes of the two timbers to be jointed. For instance, as it is stated in *Rivington* :

"In some cases the relative position of the girder and beam is determined by other parts of the framing, as, for instance, in a framed floor, where more room must be left above for the bridging joists than below for the ceiling joists. This involves a higher position for the tenon so as to bring it above the neutral axis of the girder. In every case it should be

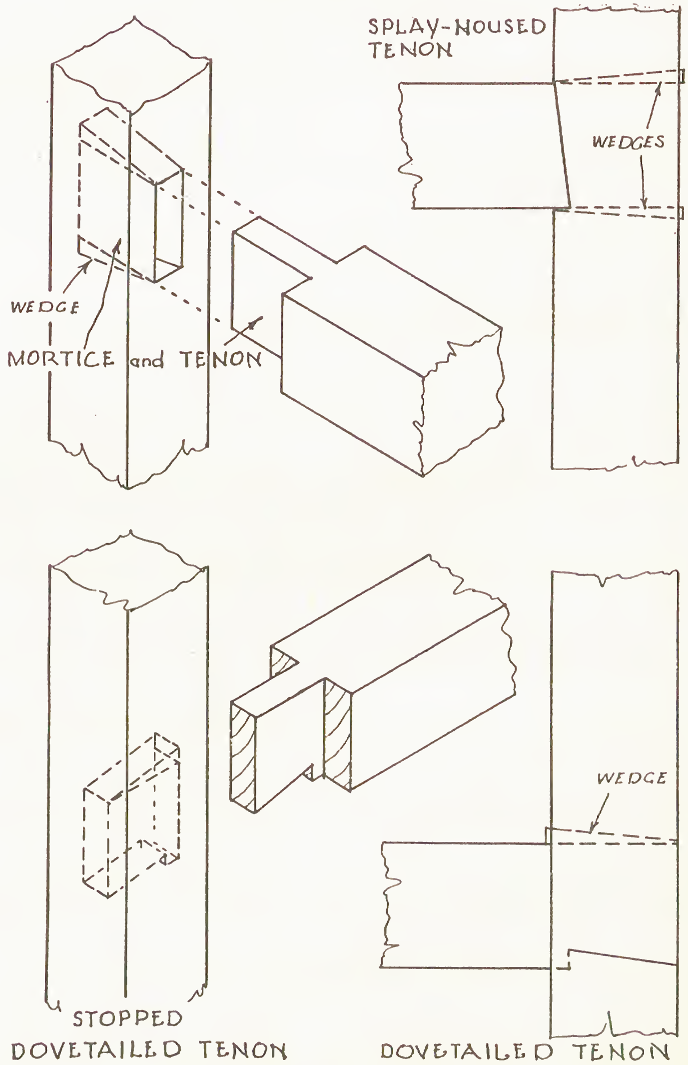


Fig. 41.—Mortise and tenon joints.

considered whether the girder or the joist can best afford to be weakened ; if the former has an excess of strength, the tenon may be kept low, so as to avoid weakening the joist ; but if the joist has more strength to spare than the girder, the mortise should be above the neutral axis of the latter, even though the tenon may be high up on the joist. In practice, it more frequently happens that the joists, rather than the girders, have an excess of strength ; so that it is usual with carpenters to place the lower edge of the mortise on the neutral axis, and to let the position of the tenon on the joists be arranged to suit the mortises.”

An economical form of joint used in jointing the trimmed joists to the trimmer, used mostly in Western America, is constructed as follows :

The trimmer is built up of three planks, the outer one of which is cut with the splayed shoulder like saw teeth, and the ends of the trimmed joists are cut to fit on to these shoulders. This provides a good bearing without cutting the trimmer unduly, and the latter is built up plank by plank after the first one has been spiked to the end of the trimmed joists.

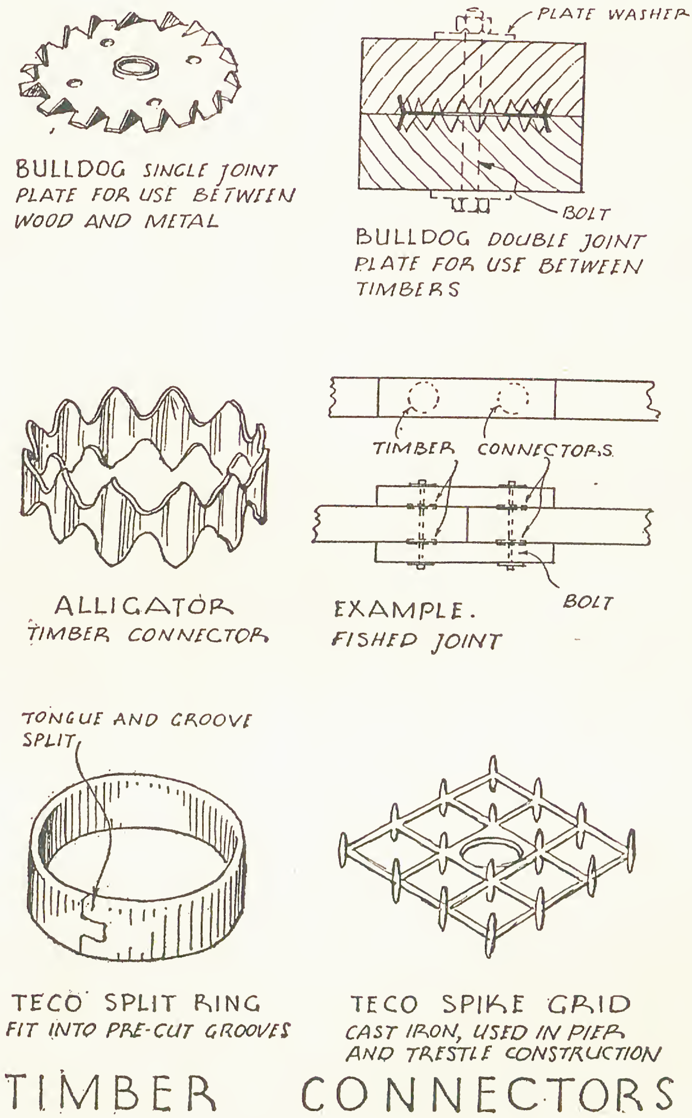


Fig. 42.—Timber connectors used with bolts distribute the stress over a wider area of material than do ordinary bolts used alone. Timber of smaller section can therefore be used.

FRAMING JOINTS

These, with the exception of the various forms of dovetail halvings, are used mostly in roof and partition framing, and will be found described under those headings.

The Chase Mortise is the name given to a special joint used for fixing the ceiling joists to the binder in a double floor. It consists of a bevelled mortise cut horizontally in the binder, so that the tenon on the ceiling joist may be slid horizontally or sprung into position, which would otherwise be a difficult operation owing to the timber in which the mortise is cut being already in a fixed position.

Wedges are used frequently in tightening up joints in carpentry, as owing to the sizes of the timbers used, the shrinkage is liable to be great. The ends of tenons in floors are frequently wedged, the mortise being cut slightly dovetailed for this purpose, *i.e.* wider on the side from which the wedges are driven. They should be of straight-grained wood left from the saw and dipped in thin glue.

It is sometimes required to tenon a timber into another fixed timber in such a position that the back of the fixed timber cannot be got at, and at the same time it is required to form a joint which will resist tension. For this purpose a dovetailed mortise is cut in the fixed timber and an ordinary tenon of the requisite dimension necessary to enable it to pass through the narrow part of the dovetail mortise. To expand this tenon so that it will fill the dovetail mortise, several small wedges of hardwood are driven into its end and left projecting. This has the result of expanding the tenon when the outer ends of the wedges come into contact with the back of the dovetailed mortise as the tenoned timber is driven home. This operation is termed *Fox Wedging.*

Pins.—The pins used in carpentry, as for example in the tusk-tenon joint, may be of hardwood or iron. The wood pins are made from strips of wood *torn* from the balk. In order to tighten up a joint in pinning, the hole through the tenon is bored a little nearer to the shoulders than the holes through the mortised timber, with the result that when the joint is fitted together and the pin driven the timbers are pulled up tight. For this purpose an iron pin, known as a draw-bore, is used, and the operation is termed *Draw Boring.*

An Alternative Joint sometimes used for connecting floor joists to trimmers is known as a dovetailed housing, but it is not one to be recommended, as in forming the mortise it is necessary to cut across the fibres of the trimmer. This joint consists of a vertical dovetail chase cut in the trimmer and a vertical dovetail mortise cut on the end of the trimmed joist after a notch has been cut out of its bottom end. The dovetail mortise and the tenon have the bottom edge splayed outwards and downwards, thus affording an additional resistance to tension.

FLOOR BOARDS

The *Covering* over the floor joists is formed of boards cut in widths varying from batten width 7 inches to strips 3 inches wide. The boards should be sawn at right angles across the annual rings. This is termed *Rift Sawn*, and it reduces the trouble likely to arise from shrinkage. In the last matter, it should be noted that, other things being equal, the narrower widths afford less opportunity for shrinkage.

The Thickness of Floor Boards is usually $1\frac{1}{4}$ inches, and they are supplied planed on both sides with their edges squared for plain butt joists; or grooved and tongued; rebated, tongued, and grooved; splayed, rebated, tongued, and grooved; or they may be grooved for hardwood dowels. They are laid in single thicknesses across the floor joists at right angles to them; but where special floors are required, they may be in two thicknesses, the lower floor being then laid either at right angles to the floor joist or, as often seen in the United States of America, diagonally across them. The finish or upper floor is not laid until all the plastering is done, and is generally in narrow widths of hardwood—spruce and pine are used in the U.S.A. and maple in Canada, in widths so narrow as even $2\frac{1}{2}$ inches.

The Square-edged Floor Boards for ordinary work are usually, when planed, $5\frac{7}{8}$ inches wide by $\frac{7}{8}$ inch thick, and are nailed vertically through the upper surface, the heads of the nails being punched in below the surface of the boards. However, this is a cheap method, and it generally soon looks it, especially if the timber used is only partially seasoned, as with the inevitable shrinkage the joints will gape often to an astonishing degree, and in bad cases the boards will curl up at their edges.

Edge Jointing.—To overcome this tendency to curl, and at the same time to enable the boards to be nailed satisfactorily through their edges, which is known as "secret nailing," the edges of floor boards are shot with a variety of moulded joints.

Rebated.—The simplest form of edge jointing is the rebate which, though it does enable the boards to be secret nailed, does not prevent cracks from shrinkage, though these cracks do not go right through the floor covering, but only down so far as the shoulder of the rebate. In cheaper work the boards are generally nailed vertically through their upper face; but for better-class work this joint has been superseded by the—

Rebated Tongued and Grooved Joint.—In this type of joint one edge of the board is shot with a groove along the centre line of its depth, and under this a projecting tongue is left. The other edge is shot with the reverse of this mould to fit when butted. The tongue under the groove is useful for secret nailing, but even when the floor board is $1\frac{1}{4}$ inches thick, only a thin strip is left for the tongue, which may easily be split in nailing or rough handling.

In this connection and in application to all forms of moulded edge jointing, the principle to be achieved is that the depth of wood *above* the first moulding, tongue, or groove should be as great as possible,

as it is on the upper surface that the wear takes effect, and should the rebate, groove, or tongue be too close to the surface, there would be danger of wear exposing it in time.

A Tongued and Grooved Joint, which consists only of a tongue on one edge fitting into a groove on the other edge, also permits of secret nailing through the tongue, which may be rounded or square. In hardwood floors this method is often employed, the holes for the nails being bored first, which prevents the possibility of splitting the tongue. The tongue

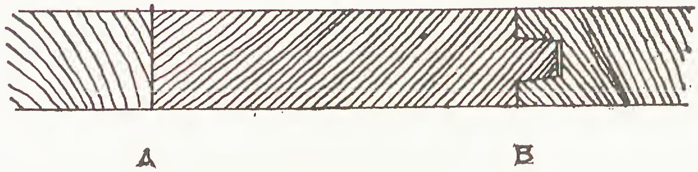


Fig. 43.

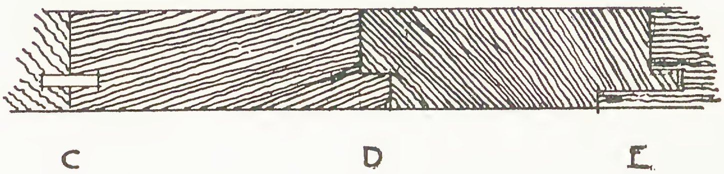


Fig. 44.

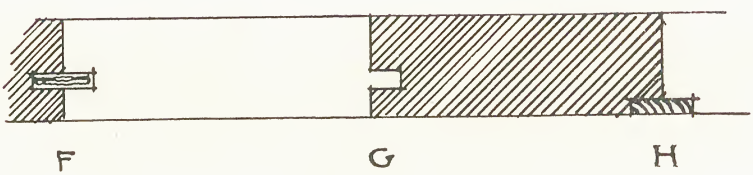


Fig. 45.

A = Butt.
B = Grooved and tongued.
C = Dowelled.
D = Rebated.
E = Rebated, grooved, and tongued.
F = Ploughed and tongued.
G = Grooved and tongued.
H = Rebated and filleted.

should be cut slightly nearer the bottom surface than the top. This method is also specially suited to flooring laid in mastic over solid concrete—the boards, generally hardwood, being nailed through the tongue into breeze fixing blocks let into the concrete.

The Splay Rebated, Grooved, and Tongued Joint is an improvement on the ordinary rebate, as it affords a better surface for nailing through—the upper surface of the tongue being splayed ; the nail consequently can be driven at right angles to the surface, and at the same time diagonally into the joist. An objection to this type of joint is that the splay necessarily uses up more of the depth of the floor board, with the result that only a thin surface is allowed for wear, which, as explained above, is

not good. However, this can be overcome by proportioning the members of the moulding with this in mind, and keeping the tongue as near to the bottom face as possible.

Other Forms of Joints used in floor boards consist of the introduction of some forms of fillet, loose tongue, or dowel.

The Rebated and Filleted Joint consists of a rectangular groove cut out of the bottom corner of the board, the space being filled with a *fillet* of oak or other hardwood $1\frac{1}{2}$ inches wide $\times$ $\frac{3}{16}$ inch thick. This joint has several advantages, the first being that it is cheap. It is also effective in sealing any gaping between the floor boards, and it offers the maximum thickness against wear of the surface. It is not, however, suitable for secret nailing. It also enables flooring to be readily and economically removed for any repair work.

In this last matter it may be noted here that all flooring laid over pipes or wires should be in short lengths, and screwed for ease in removal. The jointing should also be considered from that aspect.

Ploughed and Tongued.—This is a similar joint, so far as the outline of the section is concerned, to the tongued and grooved, but the tongue is a separate $\frac{3}{4} \times \frac{1}{4}$-inch hardwood tongue, or it is sometimes of metal, being then $\frac{3}{4} \times \frac{1}{8}$-inch wrought iron.

The Dowelled Joint is one in which the edges of the boards are shot square finish, and the joint is secured by oak pins $\frac{3}{8} \times 1\frac{3}{4}$ inches. This form may be secret nailed, though the job requires doing with exceptional care.

It will be gathered that in all joints in which secret nailing is adopted, as the boards are nailed only along one side, it depends for resistance to the curling up of the other edge on the formation of the joint, and that this, therefore, must have some form of rebate or hook. In the dowelled joint this is provided by the dowels. The distance apart of the dowels should be the same as that of the joists apart, though the dowels should not come over the joists, but be placed centrally over the spaces between them.

Summarising the uses of the different types of floor joists, the plain butt and the rebated joints are suitable for cheap work, the rebated and filleted, and the ploughed and tongued are mostly used in mill and warehouse construction, whilst the grooved and tongued and the dowelled joints are used in first-class work.

In the best-class work of all, the flooring is laid double, when the under flooring is $\frac{3}{4}$-inch deal with a butt joint and the upper layer is of some wood specially chosen, generally for its grain markings, in very narrow strips of 1 inch thickness.

Head Joints.—Floor boards which do not stretch from wall to wall require to be jointed in their lengths. They may also be cut short for removal when over wires or pipes. Though there are a variety of forms for this jointing, they are mostly confined in practice to either the *Square Butt*

joint or the *Splayed Joint*; the latter of which is necessary if the nailing is secret. In nailing the splayed joint this should be double to safeguard against splitting. The joints must consequently come over floor joists.

To secure the butt joint against any tendency of the board to lift at its end two hardwood dowels may be inserted, as in the dowelled side joint.

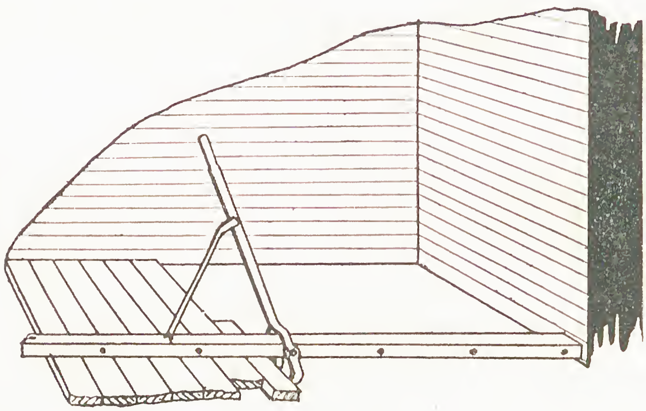


Fig. 46.—The floor dog.

A Forked Heading Joint, now rarely seen, is one in which the ends of the boards are tongued together by tapered vertical tongues and glued.

In Hardwood Floors fixed on concrete, the heading joints are tongued and grooved in the same way as for side joints, which affords a preventive measure against the lifting of the ends where fixing would otherwise be difficult.

Heading joints are to be avoided wherever possible, and with the softwoods no heading joint should be allowed in spans less than 16 feet. In plan, heading joints in adjacent floor boards should break joint, *i.e.* they should not come in the same line. In selecting boards for flooring the important point is to choose those which will be least subject to shrinkage. This will be found to be the case with boards cut with their annual rings vertical, whilst those having the heartwood uppermost will tend to curl.

Laying Floors.—Floor boards are laid either by hand or by means of a clamp known as a *Floor Dog* for bringing their sides up tight. The clamp is a form of lever which works along a timber laid over the boarding and grips the last-laid board, holding it tight against the others until it is nailed. After this has been done the clamp is moved the required distance for another floor board to be laid alongside, when the clamping operation is completed.

Fig. 47.—"Springing" floor boards.

The last two floor boards are *sprung* into place by means of a plank placed across them laid loosely in position with their lower edges touching the boards already laid and their upper edges forming a ridge. A weight, such as a man standing on it, is placed on the lower end of the lever plank, and pressure is then brought to bear on the upper, and longer, it should be noted, end of the lever plank.

Completion.—At completion the floors must be planed smooth, all nail heads having first been punched in well below the surface. When floors

are required to be polished and stained, a special machine worked by electricity is used.

Repairing Floor Boards.—From the description given of the joints used to secure floor boards—the main point required of the joint being that it should in some way or other hook the edge down—it will be realised that there is some difficulty attaching to lifting floor boards either to get at pipes, decayed joists, or damaged floor boards without causing further damage to the joint.

Where a new section of floor board is required in a tongued-and-grooved jointed floor, for instance, the new board must have the lower shoulder cut away from the groove and the upper shoulder planed on the splay; also the tongue on the other side must be splayed.

To raise the section that it is required to remove, the best method is to bore a hole with the brace and bit where the cut is required to be made and starting with this hole to saw the board across with a keyhole saw. The board must then be levered up from this cut end and wedged beyond the point where the second cut is desired. In this position it can be sawn with the ordinary saw used flat. It is important, however, that these saw cuts should be made on the splay to provide a heading joint for the new board which will fit up tight. If the cut is made at the side of a floor joist, before laying in the new board, a batten should be nailed to the side of the joist and flush with its top to provide a hold for nailing the new section to.

Relaying Floors.—Floor boards in old buildings which have become unequally worn, often with knotty projections on their surfaces, may be taken up and relaid reversed.

Runs in Roofs.—Where the space in the roof is not used for habitation, boarded runs should be provided for access to tanks, in 1-inch rough boarding. Trays of finished woodwork with chamfered fillets run round their edges will also be required in positions where tanks are to be placed. A certain amount of rough-boarded flooring is also advisable in attics for the storage of trunks.

Nails.—Floor Boards.—The nails used in fixing floor boards are called *Flooring Brads*. Though clasp nails are used, the flat-sided brad is more satisfactory, as it enters the wood without the same tendency to split it. The former are used in secret nailing, as they are stronger in resisting cross strain, and holes must be bored for these.

Nails when driven vertically into flooring must be punched in so that their heads are driven well below the surface.

Screws.—As has been said, wherever it may be required to raise the floor boards, they should be fixed with screws. In oak flooring the hole for the screw should be counter-sunk and a wood *pellet* fitted into the slot cut for the counter-sinking.

Parquet Flooring is generally the work of specialists, who will not guarantee the efficiency of the work unless laid by their own men. As

some may prefer to do this work for themselves, it will be found described under Joinery, to which it more properly belongs.

The above remarks apply equally to *Wood-block Flooring.*

FLOORING DATA

Tredgold's Table for Scantlings in Baltic Fir for Single or Bridging Joists

Span in feet.	Depth in Inches.				
	Breadth 1½ inches	Breadth 2 inches.	Breadth 2½ inches.	Breadth 3 inches.	Breadth 4 inches.
5	5¾	5¼	4¾	4⅜	4
6	6¼	5¾	5⅜	5	4½
8	7¾	7	6½	6¼	5¾
10	9	8	7½	7	6½
12	10	9¼	8½	8	7¼
14	11	10	9½	9	8
16	12¼	11	10½	9¾	8⅞
18	13¼	12	11¼	10½	9½
20	14¼	13	12	11¼	10¼
22	15	13¾	12¾	12	11
24	16	14½	13½	12¾	11¾
25	16½	15	14	13	12

Tredgold's Table of Scantlings for Girders of Baltic Pine, 10 feet apart

Length of span in feet.	Breadth in inches.											
	Depth 10 inches.	Depth 11 inches.	Depth 12 inches.	Depth 13 inches.	Depth 14 inches.	Depth 15 inches.	Depth 16 inches.	Depth 17 inches.	Depth 18 inches.	Depth 19 inches.	Depth 20 inches.	Depth 21 inches.
10	7½	5½	4¼	3½	2¾	—	—	—	—	—	—	—
12	10½	8	6	5	3¾	3¼	—	—	—	—	—	—
14	14½	10¾	8½	6¾	5¼	4½	3½	—	—	—	—	—
16	18¾	14	11	8¾	7	5¾	4¾	4	—	—	—	—
18	—	17¾	14	11	8¾	7¼	6	5	4	—	—	—
20	—	—	17	13½	10¾	9	7¼	6	5¼	—	—	—
22	—	—	—	16½	13	10¾	8¾	7½	6¼	—	—	—
24	—	—	—	19½	15½	12¾	10½	8¾	7½	—	—	—
26	—	—	—	—	18¼	15	12¼	10¼	8½	—	—	—
28	—	—	—	—	—	17¼	14¼	11¾	10	—	—	—
30	—	—	—	—	—	19¾	16¼	13½	11½	9¾	8½	7¼
32	—	—	—	—	—	—	18½	15½	13	11	9½	8¼
34	—	—	—	—	—	—	—	17½	14¾	12½	10¾	9½
36	—	—	—	—	—	—	—	19½	16½	14	12	10½

Weights on Floors.—For calculations of the strength of joists and beams the following are the weights which floors under ordinary conditions of loading have to carry in :

Dwelling-houses	1⅜ cwt. per foot super.
Public halls	1½ cwt. per foot super.
Factories	2½ cwt. per foot super.

For a Safe Working Load not more than one-quarter of the breaking load should be allowed.

Wood Fixing Blocks.—These used to be specified to be built in for carpenters' and joiners' work to be fixed to, but they are no longer considered advisable, and by some bye-laws are not permitted; as they are sources of inflammability and work loose in shrinking, coke breeze should be used instead.

Timber is measured :

(1) By the foot run.
(2) By the foot super.
(3) By the foot cube.
(4) The standard of 165 feet cube.
(5) The square of 100 feet super.
(6) The foot super as 1 inch.

Calculation.—*To find the number of feet run,* multiply the length by the number of pieces. Or alternatively in checking an invoice arrange the lengths in descending order. Total the number of pieces, and multiply by the figure representing the shortest length. Take the number of pieces of the longest length, add the number of pieces of the next longest length, and add this to the number of pieces of the next longest length, and so continue until the shortest length is reached, which do not add. Then add the two totals found, and this gives the number of feet run.

Framing Plans.—In the U.S.A. it is customary to prepare *Framing Plans* on which the size, direction, and details of the floor construction are shown. This is a very helpful practice which might well be more generally adopted in this country, as it leaves nothing to chance.

OPENINGS IN FLOORS

Staircases.—The opening in which a staircase is constructed is required to be trimmed. As has been explained, the joists at the ends of the opening are called the *Trimming Joists,* whilst the shortened joists are termed the *Trimmed Joists,* and the timber which is put in to take the ends of these trimmed joists is called the *Trimmer.* The trimming joists and the trimmer require to be strengthened—the rule for which was given above (see p. 42)—and the joints used in this framing are the *Tusk Tenon* for the ends of the trimmer, and the ends of the trimmed joists are jointed to the trimmer by a chase mortise horizontally or a dovetailed housing cut vertically, both of which joints have been already described in detail.

The term *Trimming* is used in general description of the work occasioned in framing round any opening or obstruction, such as a staircase, a lift well, a fireplace, hearth and breast, a chimney stack, and a trapdoor through floor or ceiling.

In *Staircases* the trimmer and trimming joists are usually doubled,

or a wider timber is used in accordance with the rule determining the increased strength required.

For *Fireplace Openings,* where the common joists are 9 × 2 inches, the trimmer and the trimming joists will require to be 9 × 3 inches. The trimming joist must be run at the side of the chimney breast at least 3 inches from the brickwork, and the trimmer is tusk-tenoned into these at both ends, from which it will be clear that the trimmer must be jointed to one trimming joist already in position, and the second trimming joist must then be jointed to the other end of the trimmer. The trimmed bridging joists are then fixed, in which lies the explanation of the need for special dovetailed housing into which they are slid from above, the other ends being nailed afterwards. When this last operation is complete, the wedges in the tenons of the tusk tenons should be driven in tight.

Trimmer Arch.—On the inner upright face of the trimmer the carpenter is required to fix a fillet which may be square 2 × 1 inch or chamfered into a wedge shape to carry the trimmer arch built in brickwork under the cement or tiled hearth. The carpenter is also required to form the temporary centering on which this arch is built. This arch may be a level segment or a skew arch, and the centering will be required to be shaped accordingly. In either case it will consist of two segmental ribs, one at each end, with laggings nailed between, and for the level segment the skew-back fillet mentioned above will be required on the face of the trimmer. In the skew arch the bricks rest flush against the trimmer, and are sprung from a skew back cut into the face of the chimney breast under the hearth.

Trimming, for trapdoors, is carried out in the same manner, with the exception that two trimmers will be required instead of one, as for the hearth opening.

SUPERVISION

In Purchasing Timber the main point to be guarded against is an undue proportion of sapwood. Indications of this are to be seen in the difference of colour ; and the ideal specification in this matter is that " the timber shall not contain more than 10 per cent. of sapwood " ; but where really good work is the requirement, and cost is not considered, there must be no sapwood. The presence of sapwood can be more readily detected when the timber is wet, but seasoning will not convert sapwood into heartwood.

A Good Timber, therefore, should be almost free from sapwood, large, loose, or dead knots—be porous, and give out a good ring when struck. When cut the timber should smell sweet—a musty smell is an indication of decay, and when planed the surface should have a silky lustre. The colour should be uniform, and any discoloration should be suspected as an indication of incipient rot. In coloured timbers the darkest are the

soundest and strongest, but dull red stains in any timber, called "foxiness," are an indication of decay.

Decay.—It should be remembered that whilst timber in which there is an undue proportion of sapwood, or in which decay has already begun, will decay more readily than good, well-seasoned timber, yet the best timber will not long resist damp unventilated conditions in a building. Supervision should therefore be given to the positions in which the timber is to be built. A very slight alteration in these, such as a few airbricks, may well be the cause of saving a very considerable expenditure of time and money in the future. And here it should be noted that this future is by no means so far off as might be thought, as the rate of growth of the dry-rot fungus, for instance, is surprising in its rapidity. To such an extent is this so that the timber of joists has decayed in some known instances before the building was finished.

In this matter it is not sufficient always to provide just the number of airbricks specified. The contractor should use his own discretion in this matter. An airbrick takes no longer to build in than a solid brick, and a few here and there may be the cause of the saving of a contractor's reputation. One airbrick in a confined space is little, if any, more use than none. What has to be aimed at is a cross-current of air. No amount of care and attention to this matter can ever be wasted, as it is a surprising thing that good contractors who take a real pride in the craftsmanship of their work will often allow the whole thing to be spoiled just by the lack of care and supervision in this matter of ventilation of interiors and enclosed spaces within the unseen parts of a building. Whereas the fact is that careful supervision in this matter will repay a contractor over and over again, even if he introduces the extra ventilation at his own cost—though there is no reason why he should do this, as any reasonable architect will welcome and certify for such extra precaution if the point is introduced to his notice tactfully.

Airbricks vary. In fact, it would be a good thing if the 9 × 3-inch airbrick, which often has more solid area than perforations, were discarded, and 9 × 9-inch air gratings in metal substituted.

Wood blocks, pegs, and any other temporary carpenter's timber must not be allowed to remain to be built in concrete. It is a frequent practice to leave the levelling pegs in foundation trenches. Also, it is essential that the contractor should assure himself that all shavings and chips have been entirely cleared out from under ground floors and between the joists of upper floors. This is rarely done to satisfaction. Yet if any intelligent contractor were to be asked, he would know at once that green concrete and brickwork is full of moisture. Consequently, to leave shavings and ends in such positions is to invite the very disease that all his trouble in other directions, such as obtaining and paying for well-seasoned timber, has been expended in safeguarding against.

Air gratings in upper floors and skirtings should be inserted, also in eaves and roof gables.

In inspecting the carpenter's work, on the job, the point to be looked for is the fit of the joints. Carpentry, on account of the size of the timbers, must be expected to shrink anyway, so look well to this work and its proper wedging. Wedges are not an indication of bad workmanship in carpentry, and in some structures, scaffolding, shoring, and concrete formwork, they are essential; also they are, in certain joints, used in floors and roofs. It should be remembered that to wedge metal against wood, metal wedges must be used; wood wedges driven in in such positions only become crushed and therefore useless. Note that wood keys are cut with the grain at an angle.

Though metal straps are used more in partitions and roofs, any strapping used in framed floors must be so constructed as to permit of being tightened after shrinkage has taken place.

Trimming round openings for pipes, etc., at the time of construction is a better practice than cutting away for the other trades at a later time. It saves time; and cutting may weaken the structure considerably, in fact, entirely upsetting the calculation which went to the proportioning of the timber in the first place.

Architects are not always so conversant with the allowance that should be made for "finish," and it is well to have an understanding in this matter before the job is begun. It should be clearly stated whether the sizes given in the specification indicate unwrought or wrought dimensions. An allowance of $\frac{1}{16}$th inch should be made for each wrought face.

TIMBERS USED IN CARPENTRY

The Timbers used in carpentry for the heavier work include the fir from the Baltic ports, oak, chestnut, mahogany, pitch pine, and teak.

For Panelling of the cheaper nature, American yellow pine and Christiania deals are used. Also English oak, Austrian oak, Spanish oak, sycamore, maple, and Canary whitewood are used for panelling.

For Floors.—Fir or deal from the Baltic ports is generally used, and spruce for inferior work. Oak and pitch pine make very durable floors, though the former is apt to shift.

CEILINGS

Ceilings are formed either on the underside of the floor joists in single floors, or in special lighter joists in double and framed floors, or on light joists fixed to the tie beams and collars of the roof timbers. They should be fixed from 14 to 16 in. centre to centre, and a breadth of 2 inches is the best width to afford a satisfactory nailing surface for the lathing; any greater width interferes with the *key* between the laths, and cracks will appear along the lengths of the ceiling joists if greater widths are used. Counter-lathing should be used on surfaces wider than 2 inches.

Methods of fixing.—Ceiling joists are usually fixed on plain bearings.

When the bearing is on top of a wall a timber wall plate may be used and the ceiling joists nailed to it. Where ceiling joists act as a tie to pitched roofs it is essential to nail them either to the rafters or the wall plate. Wall plates should never be built into walls as they are liable to rot, and in case of fire to endanger the stability of the wall. Galvanised iron bearing bars are now widely used to give an even bearing. In cheap work neither plates nor bearing bars are used, the joists resting on the wall and being packed at the bearing with bits of slate to bring them to one level. This is not a good method as if any of the slate packing is disturbed or is not level with the others the ceiling joists affected will settle unequally under load. The metal bearing bar has several advantages, it is cheap, easily fixed, gives a level bearing and adequate load distribution, and it lifts the joists clear of the wall and so ensures good ventilation and protection against dry rot, alway provided that an open pocket is left around the joist ends.

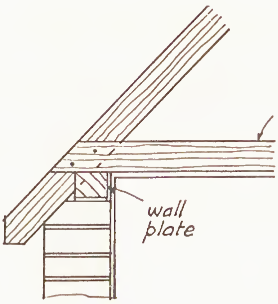


Fig. 48.—Bearing on outside wall.

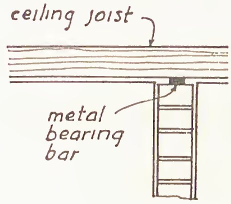


Fig. 49.—Bearing on inside wall.

Notching, filleting and chest mortising to timber binders are old methods which are now almost obsolete. The fillets nailed close to the bottom are obviously very insecure. In modern work steel binders are used (see fig 25).

Ceiling Joists are also *Strapped* by being hung from the bridging joists in a framed floor by wooden *straps*. The latter are tapered lengths of batten nailed to the side of the bridging joist, and to their bottom and narrower end the ceiling joists are attached. This method has the additional advantage that it is a good preventive of sound transmission.

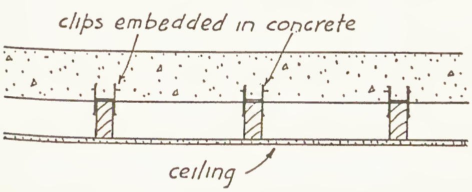


Fig. 50.—Ceiling suspended from concrete floor.

For support over long spans the ceiling joists are notched to ceiling bearers, which are hung from the roof timbers by wrought-iron hangers $2 \times \frac{1}{4}$ inch screwed to the bearer.

Trimming is formed in ceilings round chimney stacks, stair wells, and for trapdoors, in the same way as for floors, the joints usedbeing the "dovetail notch" and the mortise and tenon.

Forking Pieces.—A method of supporting the ceiling joist preferable to building in their ends is that in which a timber $4 \times 1\frac{1}{2}$ inches is plugged to the wall, having at its centre a forking lath nailed. The ceiling joist ends are *Bridled*, *i.e.* notched out in the centre of their ends to fit over this forking lath, it being necessary to slide these joists into position sideways,

when they may be nailed to the forking piece either downwards at an angle from the top, or from the sides also at an angle.

Where ceiling joists come above wood-framed partitions they are rested on the 4 × 3-inch head of the partition, and the ceiling joists for adjacent rooms should be lapped and nailed together through their sides ;

DETAILS OF SUSPENDED CEILING.

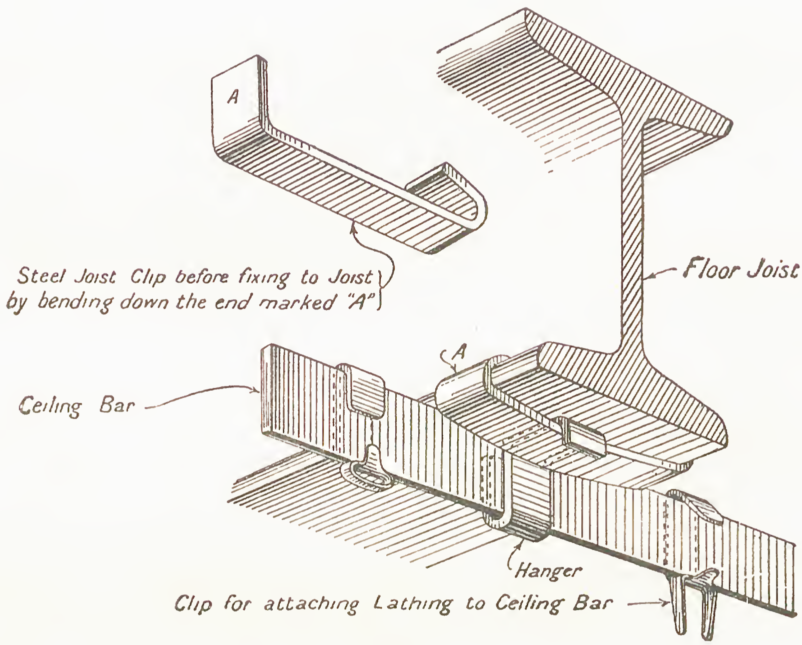


Fig. 51.

or where one of the adjacent rooms is of small width, the ceiling joist may be continuous across both spans resting on the partition head and being nailed thereto.

PARTITIONS

Where the divisions required by the plan accommodation cause walls to be built over rooms below, partitions are framed in timber. In cheaper construction the divisions of downstair rooms may also be of wood-framed partitions, but this is rarely so in modern work.

Where there is a second storey above the first-floor ceiling, the division is carried up by means of a framed partition vertically over the one below, and the upright timbers forming the dividing partitions on both storeys may be in single length, as is explained later.

Timber-framed partitions are classified as follows : (1) common partition ; (2) framed or braced partition ; (3) trussed girder partition for two storeys ; (4) brick-nogged partition.

Common Partitions.—Floor joists should be doubled to carry common partitions.

There should be a sill 4 × 3 inches at the bottom, into which the 4 × 2-inch studs are tenoned, and a head 4 × 3 inches rested on the tops of the studs. For stiffening, pieces of 4 × 2 inches are let into the space between the upright studs in a horizontal line—and are termed *Nogging Pieces.* These act as stiffeners in the height of the partitions, and alternatively they may consist of 2 × 1-inch strips notched into the faces of the studs; or a further alternative method is to nail these 2 × 1-inch strips on the face diagonally, the triangular formation being thought to provide greater stiffening support. Nogging pieces should be fixed in any partition over 4 feet in height.

The sill, where it runs across the floor joist instead of in the same direction, should be formed of two 4 × 2-inch pieces bolted together, and where door openings occur it is discontinued, the doorpost stud being 4 × 3 inches and dovetailed into the end of the sill.

The end studs of a common partition are also 4 × 3 inches and where these come against a brick wall they are nailed thereto into breeze fixing bricks, or they may be fixed by means of hoop-iron anchors nailed to their faces and turned upwards to fit in the upright joint behind a brick.

Door Openings are framed out with 4 × 3-inch posts and heads, or alternatively the head is formed of two 4 × 2-inch studs nailed together and framed through the doorposts with vertical mortise and tenons—the tenon being projected and pegged.

Note.—It will be gathered that in framing partitions every possible precaution should be taken to render the partition stiff and rigid, as, being required to carry the lath and plaster, any weakness in this respect will cause cracking. This is the purpose, for instance, of the last-mentioned wedged or pinned tenon and the nogging pieces already described.

The Heads are sometimes built into the brickwork of a solid wall at right angles to the partition, but this practice is only undertaken to hold the partition erect, and not to support its weight, as the joints of the studs to the head are not designed to resist tension. If this is required of them they must be dovetail halved to the head and strapped thereto with hoop-iron strapping.

The Studs are spaced at 12-inch centres, so that the lath ends may meet on every third or every fourth stud, according to the length of lath used.

In American construction the partitions on both floors are formed of studs and posts in single lengths, this method being termed *Balloon Framing.* The floor joists are rested on a 7 × 1-inch board called a *Ribbon,* which is let into a notch cut into the studs to receive it.

In this framing in the American method the studs are doubled at the sides of all door and window openings; and the framework is braced by diagonal 6 × 1-inch boards at the angles, *this brace* being run from the plate at the bottom to the angle post at the underside of the *ribbon.* It is

let into diagonal notches cut in the studs flush with the outer face of the studs, and is nailed to each stud with two nails.

The Combination Frame.—A better form of framing, which resembles in principle our half-timbering, is used in American construction for larger and more important domestic buildings. Though the balloon frame is used in this so far as the sills, posts, girts, and braces are concerned, the studs are run the height of one storey only, being mortised into the sill at their bottom ends and spiked to a cross timber 8 × 4 inches, known as the *Dropped Girt*, which carries the joists of the upper floor. On the sides of the outer framing parallel to the floor joists the dropped girt is

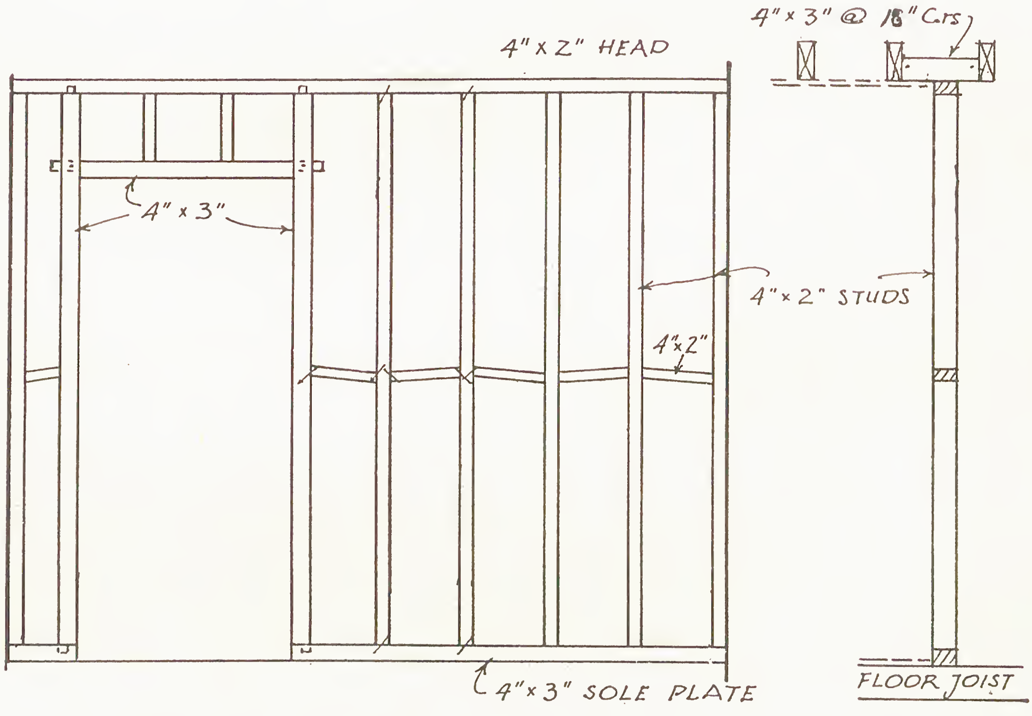


Fig. 52.—Simple non-load-bearing partition. Floor must be strong enough to carry partition. Notice method of fixing head where partition is in between joists above.

omitted, a raised girt being substituted at the same height as the floor joists, and to this the studding is nailed on these sides.

The sills are 8 × 6 inches or 6 × 6 inches, and rest on the foundation wall. (*Note.*—There is generally a basement in American houses, used as a central-heating furnace chamber, laundry, and store.) The sill is mortised to take the feet of the studs and for a diagonal brace 4 × 3 inches at the angles. The corner posts are 8 × 4 inches, and come over the halving at the angles of the sills. The studding is 4 × 2 inches except at the corners and at openings, when it is either doubled or 4 × 3 inches. The ceiling joists to the upper rooms, which are also the floor joists if another storey is used for habitation, are 8 × 2 inches and

rest on a 7 × 1-inch *ledger* let into the inside faces of the studs. Over the joist ends above this ledger a *plate* 6 × 4 *inches* receives the heads of the studs to which they are nailed downwards through the plate. This plate is often double, one timber being laid on top of the other.

The Sills resting on the foundation wall are bedded in cement mortar and set back from the outer face of the wall 1 inch to give a bell cast to the outer wall covering, whatever that may be formed of, clap boarding, shingles, or rough-cast plaster.

They should be bolted to the foundation walls with $\frac{7}{8}$-inch bolts 2 feet 6 inches to 3 feet in length, built downwards into the walling, and finished at the bottom with anchor plates, embedded in the mortar between the masonry joints. At their top ends these bolts are finished with screw nuts and plates, with which the plate is screwed down tight upon its setting on the masonry below.

It should be remembered that as a good deal of the sill is cut away for the mortise to receive the studs and the floor joists, these timbers are thereby considerably weakened. Consequently, they should be oversized rather than undersized.

The Posts, Girts, and Braces are either of doubled studs or of timbers having one dimension equal to the thickness from outside to inside faces of the studs.

The girts are jointed to the posts with a splayed shouldered mortise and tenon, which is pinned through the tenon, and the braces are mortised and tenoned to the posts and the tenon pinned. The pins are $\frac{7}{8}$ inch diameter in hardwood.

Hangers.—To avoid weakening the sill by cutting away for the ends of the floor joists, metal hangers or shoes are fixed to the side of the sills and the joist suspended in these. Alternatively the joist ends may be cut with a shouldered halving so that at least one-third of the joist rests on the top of the sill. Why the joists should not be rested wholly on top of the sills as in England, and as they are on the girts above, is not clear, but it is not a customary practice.

The Framed Partition.—The construction of the framed partition depends upon whether openings for doorways are required, and if so how many. If there is no opening the partition is framed as a *King Post Truss.*

The King Post Truss, as will be found described more fully in the chapter on Roofs, is a form of truss used more particularly in the construction of timber roofs of spans over 20 feet. However, the same principles apply to the type of truss used in framing partitions. The purpose of the truss is to carry the weight of the partition, and to distribute it at the sides on to the points on which the ends of the sill rest. This sill forms the *tie* of the King post truss, which by the tensional strain that it exerts in conjunction with the spreading action of the two diagonal *struts* or *braces* causes the partition to be self-supporting so that no additional support is required under its length.

This truss in a roof is a triangular formation consisting of a *tie-beam*

run across the span and attached to the feet of two timbers known as *Principal Rafters*, which are joined together at their upper ends by being housed into the top end of the *King post*, a vertical timber resting on and tenoned and strapped to the centre of the tie beam. From the base of this King post diagonal struts are run to a point at about the centre of the principal rafters, to which they give additional support against any tendency to sag owing to the weight of the roof.

This short description is inserted here so that the principle of the truss may be understood in its application to partitions. Any form of truss is merely the application of the principle of a triangle to construction.

In the King Post Framed Partition this triangle is formed of a sill 9 × 4 inches, representing the tie-beam in the roof truss, and two 4 × 4-inch *braces* representing the rafters and coming together at the centre of the 6 × 4-inch partition head to complete the triangle. By this means the weight of the partition and any additional weight that it carries is gathered up and concentrated at both ends of the sill. These rest on the side walls, into which should be built stone templates 13 × 9 × 6 inches for their reception.

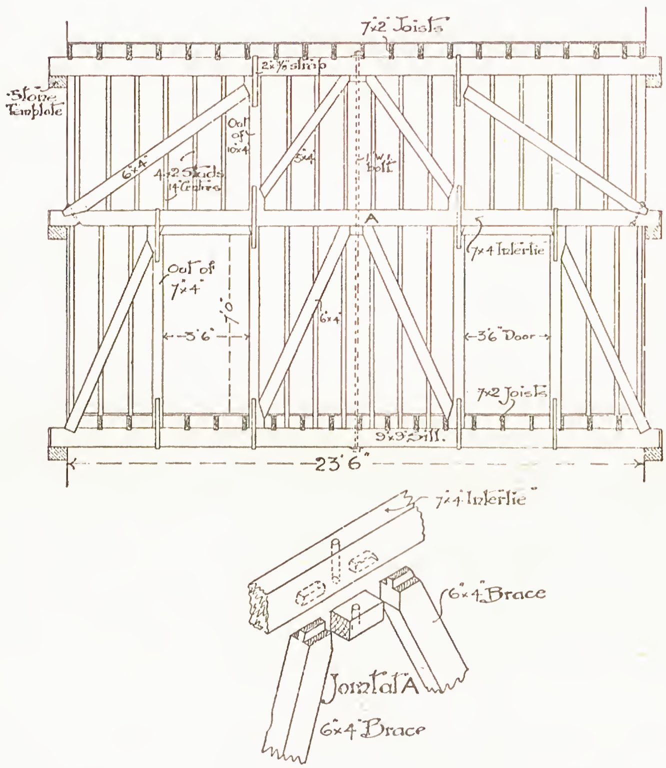


Fig. 53.—The framed partition.

Vertical Studding, consisting of 4 × 2-inch studs, are cut in above and below the braces, with their ends splayed to fit tightly where the braces cut them. Their bottom ends are tenoned into mortises cut in the sill.

Nogging Pieces of 4 × 2-inch stuff are run horizontally in two rows cut in between the studs.

The Centre Stud may be out of 4 × 4-inch stuff to form the King post, and it should be tenoned to the sill and strapped to it with a $1\frac{1}{2} \times \frac{1}{4}$-inch wrought-iron strap bolted. The feet of the 4 × 4-inch braces are fitted to the sill with a bridle joint and bolted with a $\frac{1}{2}$-inch bolt run through the foot and the sill.

A Combination of the King post trussed partition and a portion of the

same partition in which there is a door opening, formed to one side, will have the door post on the truss side, being cut out of 5 × 4-inch material to give the widened foot having a shoulder on one side, similar to that of a King post, on which the diagonal brace may be rested and into which splayed shoulder it is tenoned. The farther door post 4 × 3 inches is tenoned and strapped to the sill; and the opening for the doorway is framed over the top with a 4 × 3-inch door head, over which short lengths of vertical studding are inserted at suitable distances apart for lathing to.

The top ends of the side posts, King post, and door posts may also be strapped to the 6 × 4-inch head with $1\frac{1}{2} \times \frac{1}{4}$-inch wrought-iron straps secured with $\frac{1}{2}$-inch bolts; and to tighten the truss at completion steel wedges should be driven in between the strap at the base of the King post and the sill.

Single Doorways at the Centre of a trussed partition necessitate the adoption of what is known in roofing as a *Queen Post Truss.*

The principle of the Queen post truss in roofing is the formation of a truss suitable to distribute the weight of a roof to the side walls when the space within the truss is required to be occupied by habitable rooms. This is achieved by replacing the central King post by two Queen posts the required space apart and kept apart at their heads by a *straining* beam. The triangles at the sides of these are each formed similarly to half a King post truss. The principle, therefore, becomes the formation of a triangle with a strained rectangle in its central portion.

In the Queen Post Trussed Partition this central space is occupied by the door opening, and the two door posts represent the two Queen posts. The *sill* is 9 × 4 inches and the head 7 × 4 inches. But in this form of truss the door head, where the opening is a wide one, is continued right across the length of the partition, when it is known as an *Intertie,* and is $5\frac{1}{2} \times 4$ inches in size. The *Door posts* are 4 × 4 inches carried right up, each in one piece for a narrow opening, and in two pieces cut across by the intertie when the opening is wide, such as would be required by folding doors. The space over this wide opening is trussed with a small King post truss.

The heads and feet of the Queen posts or door posts are splay shouldered as before described to take the diagonal braces. In addition a *Straining Beam* may, if desired, be run in between the door posts under the intertie and be bolted thereto.

Alternatively, the portion of the partition above the intertie is framed into a secondary Queen post truss, the door-post lines being carried up with secondary Queen post, having a *Straining Beam* inserted between their heads and under the *head* of the partition. The heads of these secondary Queen posts are splay shouldered on the outside to receive diagonal braces run from the interties, bridle-jointed, and strapped at their feet thereto.

The weight of the partition being transmitted by this means to the side

walls, the ends of the head, the intertie, and the sill are all projected into the walls to be rested on stone templates as before. The heads of the door posts and the feet of the secondary Queen posts are strapped and bolted with wrought-iron straps run across and bolted to the intertie, and the feet of the door posts are strapped and bolted with wrought-iron straps run round the underside of the sill. In addition there may be, if required, metal rods fitted with plates and screw nuts at either end run from and through the head to the sill. These may be tightened at completion, when such a partition forms a strong support capable of carrying, not only its own weight, but that of a floor above, if required.

A Framed Partition for Two Doorways at both Sides is formed of a King post truss in the upper portion over the intertie and a bastard Queen post truss in the lower portion.

When such a partition is run at right angles to the floor joists below it, the sill must be cut at the openings for the doors at each side; consequently, the strength of the partition lies mainly in the King post truss above the intertie. No actual weight, however, is borne by the floor joists, as the King post is carried down to the centre portion of the cut sill and from its splayed foot the diagonal braces are framed into the junction of the door posts and the intertie. The secondary triangles thus formed truss the under portion of the partition, and the sill being strapped to the foot of the secondary King post and the secondary King post being strapped at its head to the intertie and to the foot of the King post of the truss in the upper portion, which itself is strapped at its head to the head of the partition, the whole lower portion of the partition, formed of triangular truss, is thus hung from the upper King post truss.

Partitions Two Storeys in Height.—Framed partitions may be carried up for two or more storeys in height. In such conditions the framing of the lower parts of the partition in each storey will depend mainly on whether provision has to be made for doorways or not, and if so, for how many.

But the partition, whatever the nature of the requirements of these lower portions, will depend mainly for its strength of support on that trussed portion between the interties and the heads. The last-mentioned head will be in the nature of combined head and sill, and should be 7×4 inches at least. The truss between this combined head and sill will be constructed in some form of trussed girder either with King post or Queen post trussing, and depending for its strength upon its triangulation. The ends of all heads, sills, combined head and sills and interties, will be projected into the walls, and carried on stone templates or padstones. The interior should be continuous and the posts cut across by them.

In all the partitions described above there should be $4\frac{1}{2}$-inch nogging pieces let in between the vertical studs as described for the single or common partition.

Joints used in Partitions.—The rigidity of any framed partition depends to a great extent upon the formation of the joints, assisted as they are by metal strappings.

Brace to Head.—The top ends of the braces where they come together are cut on the splay and tenoned. These splayed tenons come together on splayed faces and fit into a mortise cut in the underside of the head, having its ends splayed outwards to the angle of the brace.

Brace to Sill.—The brace is jointed to the sill, by means of a *Bridle Joint* and secured by a $\frac{1}{2}$-inch bolt provided with a splayed seating block at its upper end. This bolt is bored through both brace and sill.

Post to Sill.—The 4 × 3-inch post is cut out of 4 × 5-inch timber where a shoulder for the brace is required. The foot of the post is tenoned to fit into a mortise cut in the sill, and the brace 4 × 4 inches has a splayed tenon to fit into the mortise on the splayed shoulder of the post. The side of the post is chased with a groove for the wrought-iron strap $1\frac{1}{2} \times \frac{1}{4}$ inch, which groove is continued across the sill and under the bottom of the sill also. The strap is bolted to the post with $\frac{1}{2}$-inch bolts; the holes for the bolts, being bored slightly above those in the strap, cause the joint to be drawn up tight, as wedges cannot be driven in behind the sunk strap. This method is generally fairly satisfactory and, in any event, shrinkage is hardly likely to take place, whilst the timbers remain uncovered, and after that wedges would be of no more help than the bolts unless the ceiling were to be removed, of which experience provides no instance.

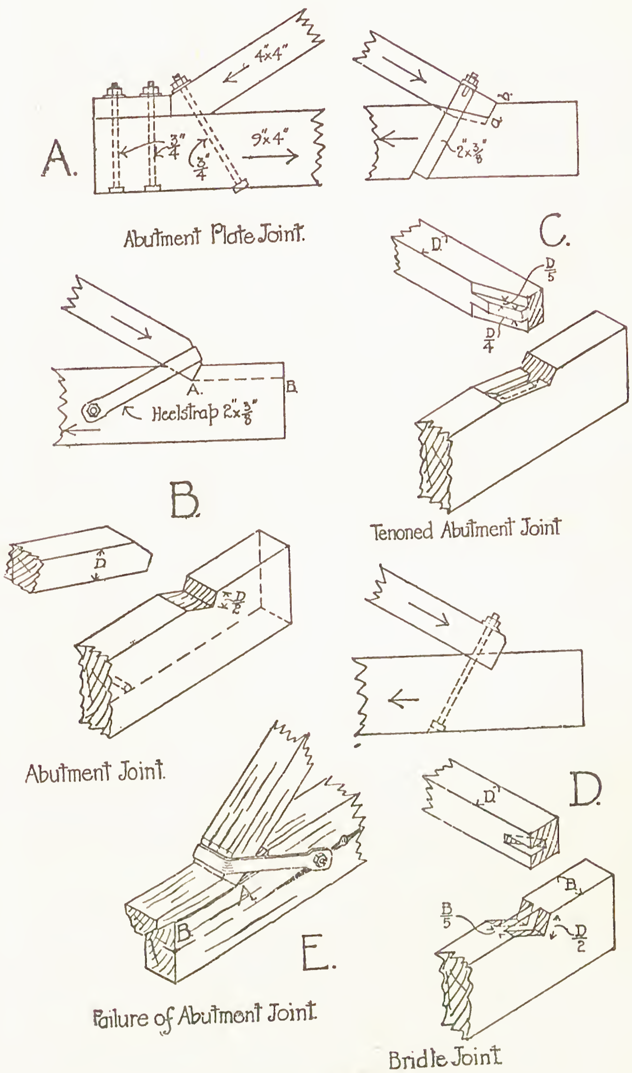


Fig. 54.—Joints used in partitions.

Studs to Sill.—The studs are jointed at their feet to the sill by a mortise and tenon, cut longways in the length of the sill.

Brace to Head.—This joint is a mortise and tenon—the two tenons

one on each brace, being cut on the splay and fitting into the one mortise cut in the underside of the head with splayed ends.

Stud to Head.—The heads of the studs are butt jointed to the underside of the head and side nailed diagonally.

Nogging Pieces to Studs are butt jointed cut a shade long and driven in with the hammer and nailed end on from the other face of the stud; or, alternatively, cut splayed and side nailed from top and bottom of the nogging piece set diagonally.

As a further alternative the nogging pieces are replaced by 2 × 1-inch nogging strips let into chases cut in the face of the studs and nailed.

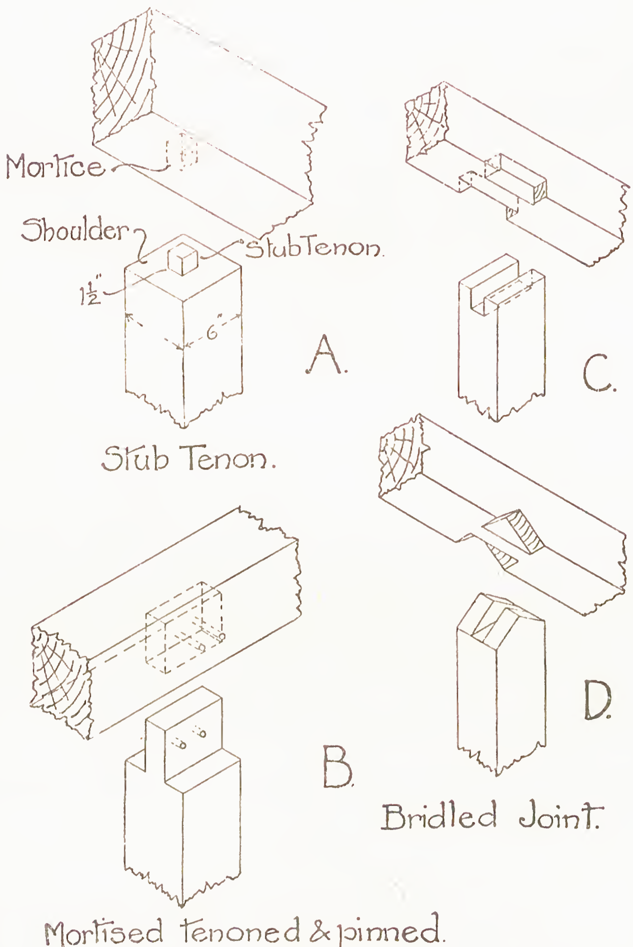


Fig. 55.—Joints used in partitions.

Post to Head and Post to Intertie are mortised and tenoned.

Door Head to Door Posts.—These are jointed by means of a tenon cut on the door head with a tongue projecting through the tenon and wedged or pinned with hardwood.

Brace and Head, and Brace and Intertie Above and Below.—One mortise is cut in the horizontal timbers for the tenons on both post and brace, and the foot and head of the brace is splayed on the tenon shoulders and on the other face which comes against the upright timber.

Brace into Sill.—In the trussed portion over the intertie the brace is let into the sill above it with an oblique tenon. But in the centre, where two braces come together under the intertie, they abut on to a straining piece 4 × 2 inches, and are themselves obliquely tenoned. The straining piece is spiked to the intertie; and the tenons and the braces are so cut that their centre lines meet at a point on the centre line of the sill, which, as has been said, in this double-storey trussed partition is a composite head and sill 7 × 4 inches.

Foot of Side Post and Sill and Post and Brace.—The foot of the post, enlarged to 5 × 4 inches, is cut with a splayed shoulder to take the brace framed in at an angle with an oblique mortise and tenon. The joint between the enlarged foot of the post and the sill is an ordinary mortise and tenon.

The Post to Intertie from below is jointed with an ordinary mortise and tenon. The intertie is carried through 3 inches beyond the side post to rest on the wall on a padstone.

The Post and Brace to Intertie from above is jointed by a combination of mortise cut to receive both tenons. That between post and intertie is an ordinary tenon, but to afford additional strengthening to the bearing of the brace, a splay is cut in this part of the shoulder of the mortise, having a vertical end-face notch flush with the side of the post.

The Joint between the Composite Head and Sill, Post, and Brace.—The brace is housed into the sill with a bridle joint and butted against the foot of the post, on which there is no enlarged shoulder but a simple mortise and tenon cut just behind the bridle seating.

Head of Door Post to Intertie.—The joint here consists of a simple tenon cut on the post to fit a simple mortise in the intertie.

Foot of Door Post and Sill.—A stronger form of joint than a simple mortise and tenon is required here to resist side pressure. This consists of a bridle joint.

Brick-nogged Partitions.—In old-time buildings the wood partitions having the spaces between the studs filled in with 4½-inch brickwork were more frequently used than is the case to-day when Portland cement and many new forms of light partition blocks have superseded the brick-nogged partition to a great extent.

The surface of the brickwork projects slightly beyond that of the studs and forms a good "key" for plastering; though, unless the timber is exceptionally well seasoned, there is likely to be cracking of the plaster over the lines of the timber framing owing to contraction of the wood on drying out.

The Studs or Upright Timbers, 4 × 3 inches, are spaced apart from 2 feet 3 inches to 3 feet at distances a multiple of a brick length. They are framed in between a 4½ × 3-inch sill and a 4 × 3-inch head, either with a butt joint or a mortise and tenon if desired.

The Door Posts, which are 4 × 3 inches, are mortised and tenoned at the foot to the sill, and may either be also mortised and tenoned at the head or only butted.

The Head to the Door is 4 × 3 inches and is framed to the posts by a bevelled housing with notched shoulders—the tenon being cut with its greatest width vertical and projected through the post, and pinned horizontally with a wedge-shaped pin driven in from the side. The door posts are secured, if necessary, to the brick nogging by hoop-iron bonding, nailed to their sides and turned upwards at the end built into the brickwork.

The Foot of the Door Post is let into the $4\frac{1}{2} \times 3$-inch sill with an ordinary mortise and tenon joint.

Narrow Partitions.—Space may be saved and the floor area of rooms increased slightly by reducing the thickness of the partitions. This is effected by erecting the studs and posts with their smaller dimensions in the thickness of the partition instead of on the face. With a 4×2-inch stud fixed with its 2-inch dimension running through the partition, the finished thickness of the partition so formed plastered both sides will be 4 inches instead of the usual 6 inches. This saving may not seem to

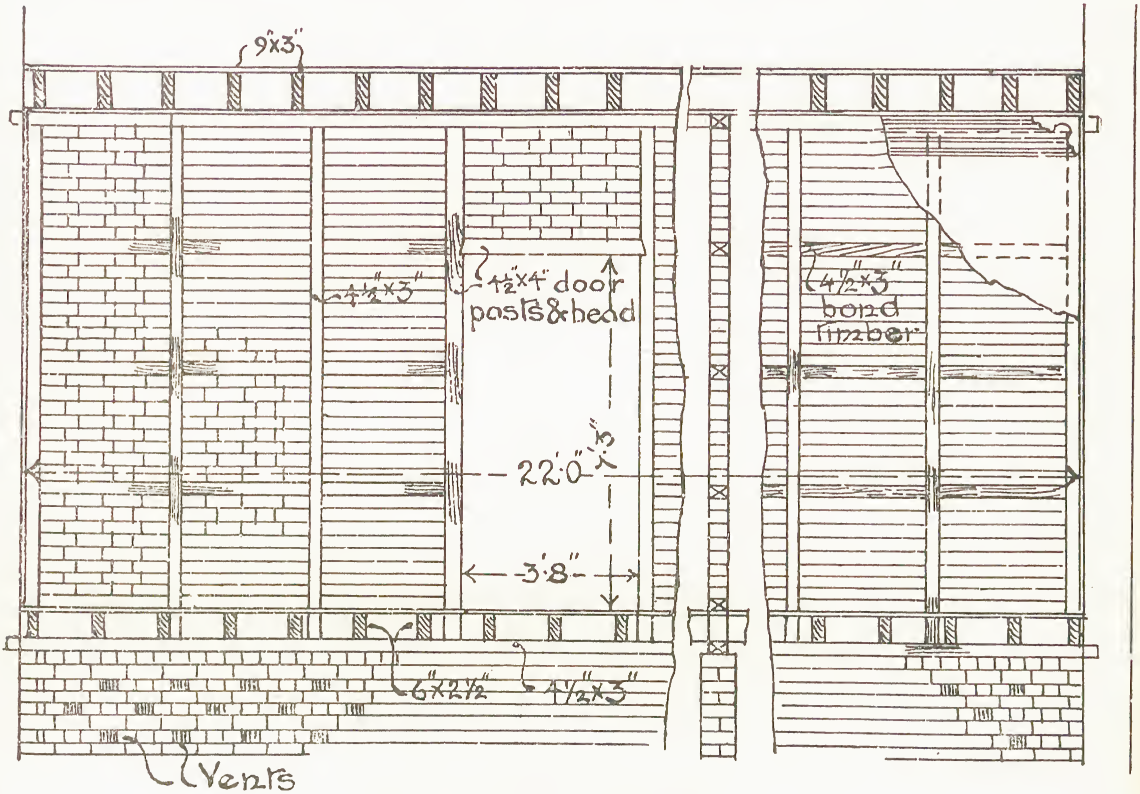


Fig. 56.—A brick-nogged partition.

amount to anything worth while. But when it is multiplied by the number of the partitions it will be appreciable, especially in the planning of the small house or cottage, in which every inch is of importance, in particular in such restricted areas as it is only possible to afford to bathrooms and upstairs lavatories, for example.

Weights and Scantlings of Partitions.—The following particulars concerning partitions are given in *Rivington* :

	Pounds per Square.
The weight of a square of partitioning may be taken at, from	1,480 to 2,000
The weight of a square of simple-joisted flooring, without counter-flooring . .	1,260 to 2,000
The weight of a square of framed flooring, with counter-flooring	2,500 to 4,000

Scantlings for the principal timbers of a partition bearing its own weight *only* :

4×3 inches for bearing not exceeding 20 feet.
$5 \times 3\frac{1}{2}$ inches for bearing not exceeding 30 feet.
6×4 inches for bearing not exceeding 40 feet.

If the partition has to sustain the weight of a floor or roof, the sizes of the timbers must be increased to meet the additional strain that will come upon them.

The filling-in pieces must be just thick enough to nail laths to, about 2 inches.

Any timbers more than 3 inches wide on the face, to which the laths are nailed, should have the corners taken off so as not to interrupt the key for the plaster.—*Tredgold.*

Metal Lathing is used on timber-framed partitions in place of wood, but the fixing of this devolves upon the plasterer rather than the carpenter.

Patent Partitions.—Whereas the construction of patent partitions being mostly formed of some kind of clay block, their construction is carried out by the bricklayer, though the carpenter may be required to saw such blocks as can be sawn, and to fit fixings and wedges therein as the work of erection proceeds.

Rough Grounds.—The fixing of rough grounds in these and in wood partitions for door frames is also carpenter's work. These consist, for ordinary door frames, of $3 \times \frac{3}{4}$-inch grounds having 2×1-inch backings dovetailed or housed into them horizontally.

For Skirtings the rough grounds—$2 \times \frac{3}{4}$ inch, two horizontal in the height of an ordinary skirting, or the upper one may be $2 \times \frac{3}{4}$ inch and the lower $1\frac{1}{2} \times \frac{3}{4}$ inch—are halved on to the rough ground to the door.

CHAPTER 4

CARPENTRY: ROOF CONSTRUCTION

The Roof is the most exposed part of the building and it should be stiff enough to resist wind pressure and any occasional loads, such as snow or workmen, without undue deflections which might disturb the roof covering and cause leakage.

The carpenter may be required to fix insulating material in the roof structure with the double object of making the interior cool in summer and reducing the escape of heat from the building in winter.

The Pitch, i.e. the angle which the roof forms with the horizontal, has been discussed under the chapters on Roof Coverings (Chapters 12 and 13 of Vol. II). The pitch must be designed to suit the roof covering and relative exposure, but the greater the pitch the more material and labour are required.

Definitions.—The following terms are used in connection with *Roofs*, and have an application to the construction of the roof framing which is constructed by the carpenter.

Battens.—These are the strips of wood from $2 \times \frac{3}{4}$ inch to $2 \times 1\frac{1}{2}$ inches laid over the rafters or boarding on a roof to which the covering material is fixed. The battens may be fixed horizontally or vertically, when they are termed " counter or cross battens."

Binders are stiffening timbers framed in between tie-beams (see below) and afford bearing for the ceiling joists when the principals are too widely spaced.

Boarding, generally $6 \times \frac{7}{8}$ or 6×1 inch, laid across the rafters under the battens to afford additional protection from the weather and from loss of heat from the interior. Feather-edge boarding in 4-inch widths is also used for tiled roofs, the boards being laid with their thick edge uppermost and so saving battens.

Cleat.—This is a splayed block fitted in against the underside of a *Purlin* (see below), and fixed on the upper edge of the *Principal Rafter* to give additional stiffness to the fixing of the purlin.

Collar Beam is the name given to a tie in a roof when the tie is situated higher up in the length of the rafters than at the level of a line connecting their feet. In the latter portion it is known as a tie beam. It is generally used when it is required to make use of the space in the roof. The strain which the collar resists is tensional, but the form of construction is not a good one, as the tendency of the lower parts of the rafters to push the

walls outwards is not sufficiently resisted. This has been effectively overcome by a combination of collar and bracket.

A Fascia is a board generally 1 inch thick, and of whatever dimension in breadth that is required by its position, fixed to the feet of rafters to carry the rainwater gutter. It may be framed up in conjunction with a soffit to form a cornice.

A Gutter in carpentry consists of short lengths of rafters run across to form a sloping surface behind vertical faces in a roof, and boarding with which the rafters are covered. The rafters are termed *Gutter Bearers* and the solid blocking under the bearers is termed the *Gutter Plate.*

A King Rod is a metal rod of requisite dimensions used in supporting the centre of a collar beam in a couple-close roof when the weight of the ceiling joists, owing to the span, might tend to cause the collar beam to sag.

A King Post is an upright timber used in substitution of the last in the construction of roofs over a wider span when diagonal struts are required to be run from the foot of the King post to give additional support to the centre of the roof slope. *A King Post Truss,* the construction of which is described later, having such a central post as this, is suitable for roofs up to 30 feet span.

The Purlin is a timber run horizontally over the principal rafter to give the common rafters support at the centre of their lengths.

Principal Rafters are fixed at their upper ends by a tenon joint to the heads of the King post and mortise on the splay into the tie beams at their bottom ends. They serve the purpose of forming part of a truss which supports the roof and of carrying the purlins. The principal rafter is supported at its centre by a *Diagonal Strut* from the foot of the King post.

The Tie, Tie Beam, or Tie Joist is the timber run from the feet of the rafters from one side of the roof span to the other to tie them together and so prevent the roof from spreading. In a King post truss the tie beam is called the King tie. This member is in tension so far as the weight of the roof is concerned, but when it carries the ceiling joists it is subjected to a downward pull, and is therefore strapped to the foot of the King post to resist this additional strain.

Rafters, Common.—Whilst the principal rafters are the spanning members of the roof truss or principal, the common rafters are those spanning the roof throughout its length spaced at 14-inch centres and run from ridge to wall plate.

The Ridge is a board usually $1\frac{1}{2}$–2×7 inches and above, run centrally at the apex of the span of a roof. It affords a fixing to the top ends of the common rafters splay cut to fit flush against its sides, and where there is a King truss it is supported in its length by the King post, into the head of which it is let.

The Ridge Roll is a rounded batten nailed to the top of the ridge where the ridge is to be covered with metal.

Soffit or Soffite.—This is actually the under surface of any part of a building seen when looking upwards, as for instance, the underside of a staircase. The term has particular application to roofs as the under surface of the eaves projection when this is boarded up. To afford support to the boarding which forms the soffit, short ends of timber are built into the wall horizontally and fixed to the sides of the projecting rafter feet and on to the underside of these the soffit boarding, which is generally tongued and grooved matched lining, is nailed. These short ends are called *Planceer Pieces.*

Sprocket Pieces.—To afford additional projection to the eaves, and at the same time to lessen the angle or pitch of the roof at its lower part and give it a formation known as *bell-cast,* short lengths of 4 × 2 inches are nailed to the sides of the rafters which themselves, where there is a sprocket piece, are finished by being bird's-mouthed on to a wall plate, whilst the sprocket pieces are notched over the wall plate and projected beyond to form the eaves and to carry the fascia board.

Struts in roofing are diagonal members inserted to take compression stresses and are an essential part of the King and Queen post trusses, being run from the feet of the King and Queen posts generally to a point underneath the purlin. The feet of the posts are shouldered and jointed to receive these in a manner which which will be found described later, under the description of the joints used in roofing.

Templates.—This is another term that has more than one application, which is a frequent occurrence in building construction. The original meaning of *template* is a pattern of the section of a moulded or shaped piece of material, such as that of a stone used in a cornice. But the meaning of the word when used in roofing is a stone used under a beam to spread the weight carried over a larger area, as, for example, under the ends of a tie beam which would otherwise be rested on brickwork, a flat stone considerably larger than a brick is inserted to distribute the weight carried over a larger area in the wall.

Tilting Fillet or Tilter.—This is a triangular-shaped batten used to give an upward turn to the line of the roof-covering material either when it comes against a vertical face or at the eaves and sometimes at the verges. A tilting fillet is also used for a double purpose in lead-covered gutters, the first being to provide an edge and a fixing to the leadwork, and the second to tilt up the roof covering at its point of projection over the leadwork.

Truss.—As is explained later, in description of the various types of roofs used, when spans above a certain width are required to be roofed, the strength afforded by the common rafter alone would not be sufficient. To assist these, trusses are built in at certain distances apart in the length of the roof, and these support timbers run the length of the roof, and known as *Purlins,* which give support to the common rafters in their length, it may be at their centre only or at other points as required. To carry these purlins and to brace the whole roof, and at the same time to

tie in the walls, a timber framing built on the principle of the triangulation of forces is formed. This is known as a *Truss*.

In roof construction there are two traditional forms of truss: *the King Post and the Queen Post.* These are described in detail later, it being sufficient for the present purpose if it be mentioned that the King post truss is to be distinguished from the Queen post by having one central upright support, whereas the Queen post has two vertical supports spaced at equal distances on either side of the central line of the span. In modern practice these trusses have been almost superseded by the lattice-framed and Belfast trusses which are more efficient and economical.

Wall Plates.—To receive the ends of the rafters and also the ends of the tie beams to trusses, plates of timber are run along the walls and are known as wall plates. The shape, sizes, and purpose are similar to those wall plates used in floor construction ; but when the wall plate is run across the ends of the tie beams in a trussed roof to carry the rafter ends, it is termed a *Pole Plate.*

SINGLE ROOFS

Lean-to.—This is the simplest form of pitched roof consisting of rafters in one length run from a lower level at one end to a higher level at the other end, in one span.

Span is the distance between supports measured between the centres of the bearings.

Rafters are timbers from 3 × 2 inches upwards, depending on the span stretched from wall to wall to carry the roofing material. For ordinary tiles and slates they are usually spaced on 14-inch centres.

A Flat Roof is the simplest form of single roof, and in this type the rafters are run from one wall to another from points approximately level, though in fact a slight slope is given for drainage. For a span of 8 feet the dimensions of the rafters required for a flat roof would be 6 × 2 inches. It should be understood that the rafters are set on edge, *i.e.* with the larger dimension vertical.

Double Span or Couple Roofs.—All these had their origin in a framework, either resting on the ground or on low foundation walls, constructed of pairs of bent trees leaned together in the form of a rough Gothic arch. This framework was frequently strengthened by two tie beams and four wind braces, the whole being fastened together by wooden pegs. The formation of the two bent trees laid together at their top ends was known as a fork or crux. Examples of such roof construction are still to be seen in various parts of the country, " Tea-pot Hall " at Scrivelsby, near Horncastle, in Lincolnshire, being probably the best known.

The Couple Roof consists of two series of rafters run from walls of the same heights to a point above and centrally over the span. This point of

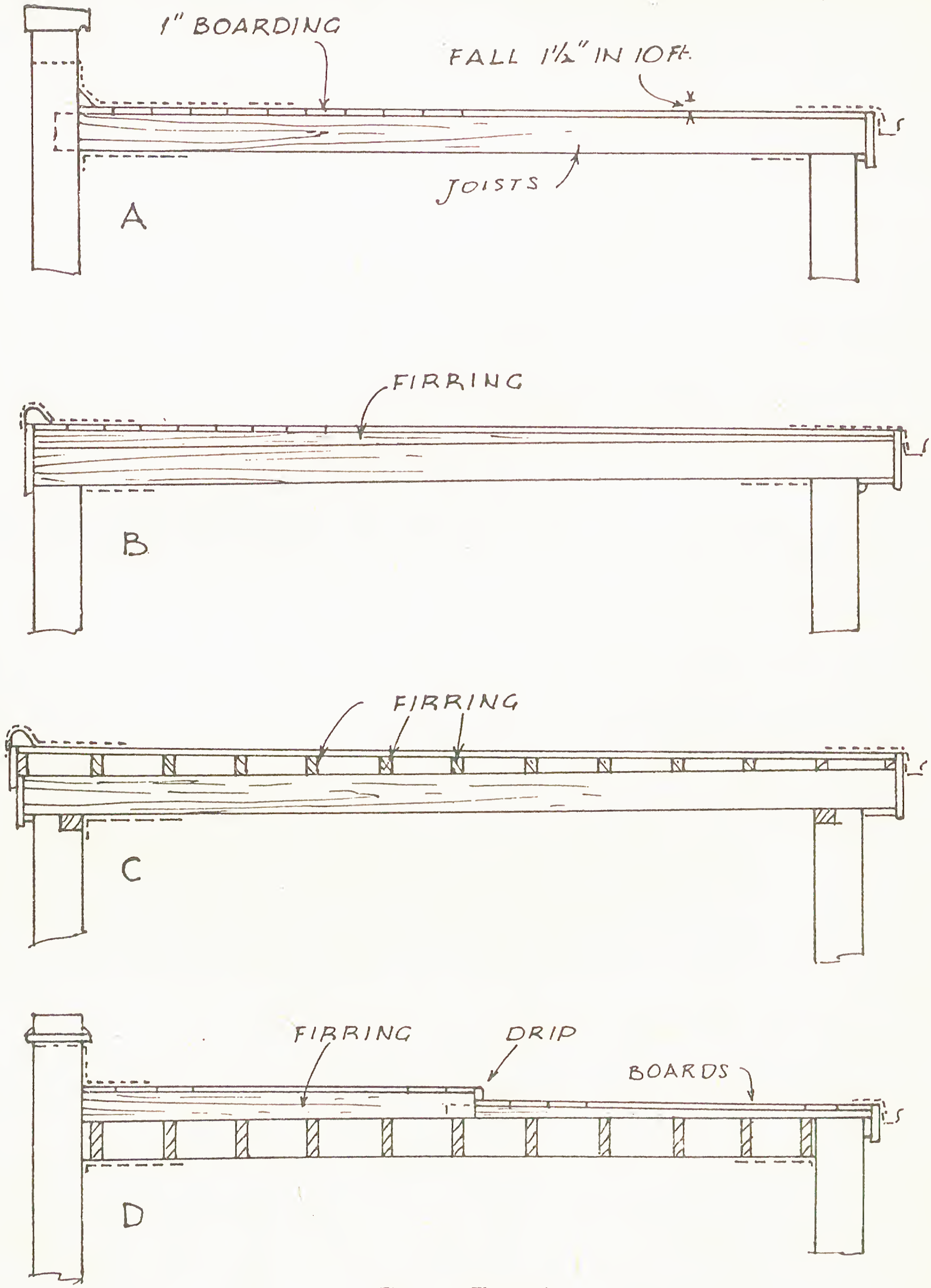


Fig. 57.—Flat roofs

A. Joists laid to fall for drainage.
B. Tapered firring pieces to give surface fall
C. Bevelled firring pieces laid across joists.
D. Tapered firrings in two sections to form drip for metal roofing.

junction is called *the Ridge*. To stiffen the roof in the length of the ridge, a board, generally $9 \times 1\frac{1}{2}$ inches, is erected between the top ends of the

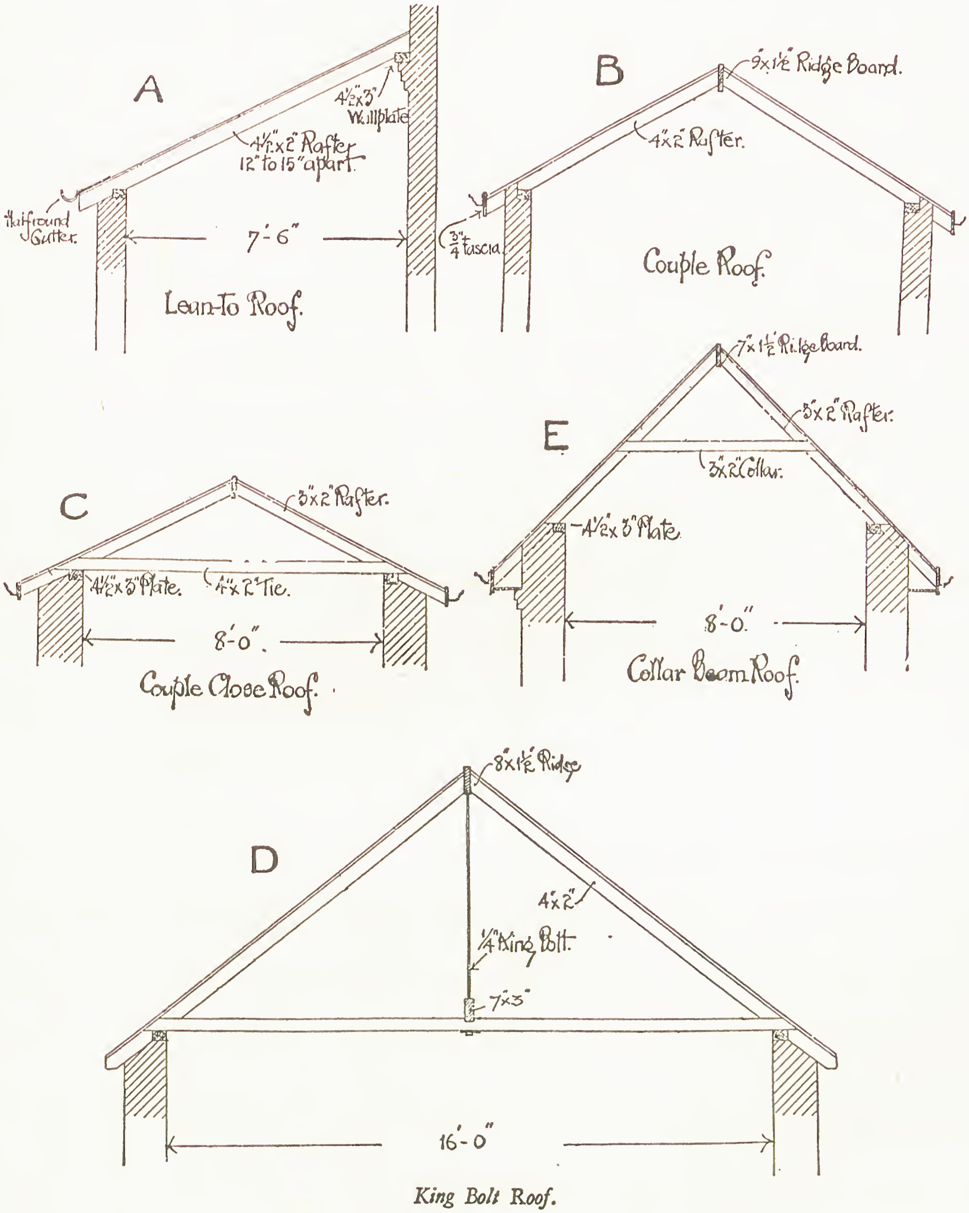


Fig. 58.—Small-span pitched roofs.

rafters which are cut splayed to fit exactly against it, being nailed thereto with *cut-clasp* nails, the last remark applying generally to the nailing of rafters in all forms to roofs.

The couple roof is suitable for spans up to 12 feet under ordinary conditions of stress and support.

The Couple-close Roof.—As will be readily grasped, the weakness of the couple roof is that it affords a lessened resistance to the tendency caused by the weight of the timbers, and the roofing material that they carry, to push the supporting walls outwards. In fact, the only resistance offered against this spreading stress in the lower positions of the rafters is that existing in the rigidity of the walls, which depends mainly on the strength of the mortar binding the walling materials together. As will be conceived, this strength of resistance is not great. Consequently, for spans over 12 feet and up to 16 feet a tie beam about $5 \times 2\frac{1}{2}$ inches or 6×2 inches is run across from the feet of the rafters where they rest on the wall plates, the tie being nailed to the sides of the rafters or sometimes dovetailed halved and nailed to afford additional tensile strength to the joint.

The feet of the rafters in these two roofs generally are either bird's-mouthed at their ends and so fitted down on to the inner top corner of the wall plate, at which point the rafters terminate, or they are notched over the outer top corner of the wall plate and are continued past it to form the projection for the eaves. In the former method, *i.e.* where the rafters are terminated on the plate, if a projection for the eaves is required, this is afforded by the addition of a sprocket piece, which is nailed to the side of the rafter and notched over the outer top corner of the wall plate.

The tie mentioned above is in tension, which resists the tendency of the rafters to spread outwards and push the walls in that direction.

Collar Roof.—Where greater head-room is required than that afforded by a couple-close roof, the tie is placed at the height required to form a ceiling, being jointed to the rafters as before either by nailing or by a dovetailed halving and nails.

This type of roof is also suitable for spans up to 16 feet, but it is not so strong and therefore should not be so heavily weighted as the couple-close roof as, not tying in the feet of two rafters, it does not afford an equal resistance to their outward thrust, setting up another stress tending to bend the rafters inwards and downwards.

Double Lean-to Roof.—A form of single roof sometimes seen is that consisting of two lean-to roofs forming a gutter centrally, though what is the exact purpose or advantage of such a form over that of a couple-close roof is not clear, unless it be that it affords a cheaper method of covering a wider span. The gutter at the centre is formed on bearers which require a beam to support them, and this beam, if of any considerable length, will require some intermediate support, such as would be afforded by a post. Consequently, it is open to doubt if in fact the amount of timber and workmanship is much, if any, less.

The Scantlings for Collar-Beam Roofs.—Pitch up to 30 inches. If 45°, add 1 inch to depth of rafters. As given in *Rivington*:

Span.	Rafters. One foot apart, or centre to centre, if very exposed site. Countess slates on $\frac{3}{4}$-inch boards. Rafters not to be cut into in fixing collars.				Collars.	
	Thrust taken by walls or ties. Compression collars half-way up.		Walls incapable of taking thrust. Tension collars quarter-way up.		From quarter- to half-way up.	At any height.
	No ceiling.	Ceiled to collars.	No ceiling.	Ceiled to collars.	No ceiling.	Ceiled to collars.
Feet.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
	$1\frac{1}{2} \times 2\frac{1}{2}$	$1\frac{3}{4} \times 3$	$2\frac{1}{4} \times 3\frac{1}{4}$	$2\frac{1}{4} \times 3\frac{3}{4}$	$1\frac{3}{4} \times 2\frac{1}{2}$	2 inches wide $\times \frac{1}{2}$ inch, more than $\frac{1}{2}$ inch per foot of clear length of underside of collar.
10	$1\frac{3}{4} \times 2\frac{1}{2}$	$1\frac{3}{4} \times 3$	$2\frac{1}{4} \times 4$	$2\frac{1}{4} \times 4\frac{1}{2}$	$2 \times 2\frac{1}{2}$	
12	$1\frac{3}{4} \times 2\frac{3}{4}$	$1\frac{3}{4} \times 3\frac{1}{4}$	$2\frac{1}{4} \times 4\frac{1}{2}$	$2\frac{1}{4} \times 5$	$2 \times 2\frac{3}{4}$	
14	$1\frac{3}{4} \times 3$	$1\frac{3}{4} \times 3\frac{1}{2}$	$2\frac{1}{2} \times 5$	$2\frac{1}{2} \times 5\frac{1}{2}$	2×3	
16	$2 \times 3\frac{1}{4}$	$2 \times 3\frac{3}{4}$	$2\frac{1}{2} \times 5\frac{1}{2}$	$2\frac{1}{2} \times 6$	$2 \times 3\frac{1}{2}$	
18	$2 \times 3\frac{3}{4}$	$2 \times 4\frac{1}{4}$	$2\frac{1}{2} \times 6$	$2\frac{1}{2} \times 9\frac{1}{2}$	2×4	

If the collar is required half-way up, about $\frac{1}{4}$ inch must be added to both breadth and depth of rafters, and $\frac{3}{4}$ inch to depth of collars: but with unstable walls, ties are far cheaper, and may be at long intervals if sufficient width is given to the wall plates to enable them to take the thrust between the ties.

HOUSE ROOFS

The ordinary house roof is a single roof of the couple-close type, the ceiling joists acting as main ties. The rafters are bevel cut to the ridge and bird's-mouth cut to the wall plates On all but the smallest spans the rafters, which are usually 4 × 2 inches, are provided with intermediate supports by placing purlins 5 to 6 feet apart, as shown in Fig. 59 The purlins may be placed so that in section they slope and form a plain butt joint against the rafters, or they may be upright, in which case the rafters are bird's-mouthed to them.

Rafters are nailed or spiked to the ridge, purlins, and wall plates, and the ceiling joists should be nailed to the rafters and wall plates.

The purlins should be supported at intervals of about 9 or 10 feet. In some cases the partition walls can be built up to a height which will allow the purlins to rest on them. In others the purlins are supported on struts resting on the partition walls, as in Fig. 59. Care should be taken that these struts are so placed as to be adequately supported and the diagonal thrust resisted.

It greatly strengthens the roof to provide secondary ties at the level of the top purlins, as in Fig. 59.

Gabled Roofs.—The walls at the gable ends are built up and the ends of the purlins are built into the brickwork. If the cross-partition walls can also be built up to purlin level, it is not necessary to have struts.

It is an advantage to project the roof beyond the gable walls and finish with barge boards. Purlins, ridge, and plates should project so that rafters can be supported on the overhang. The roof covering overhangs the barge board by about 1 inch.

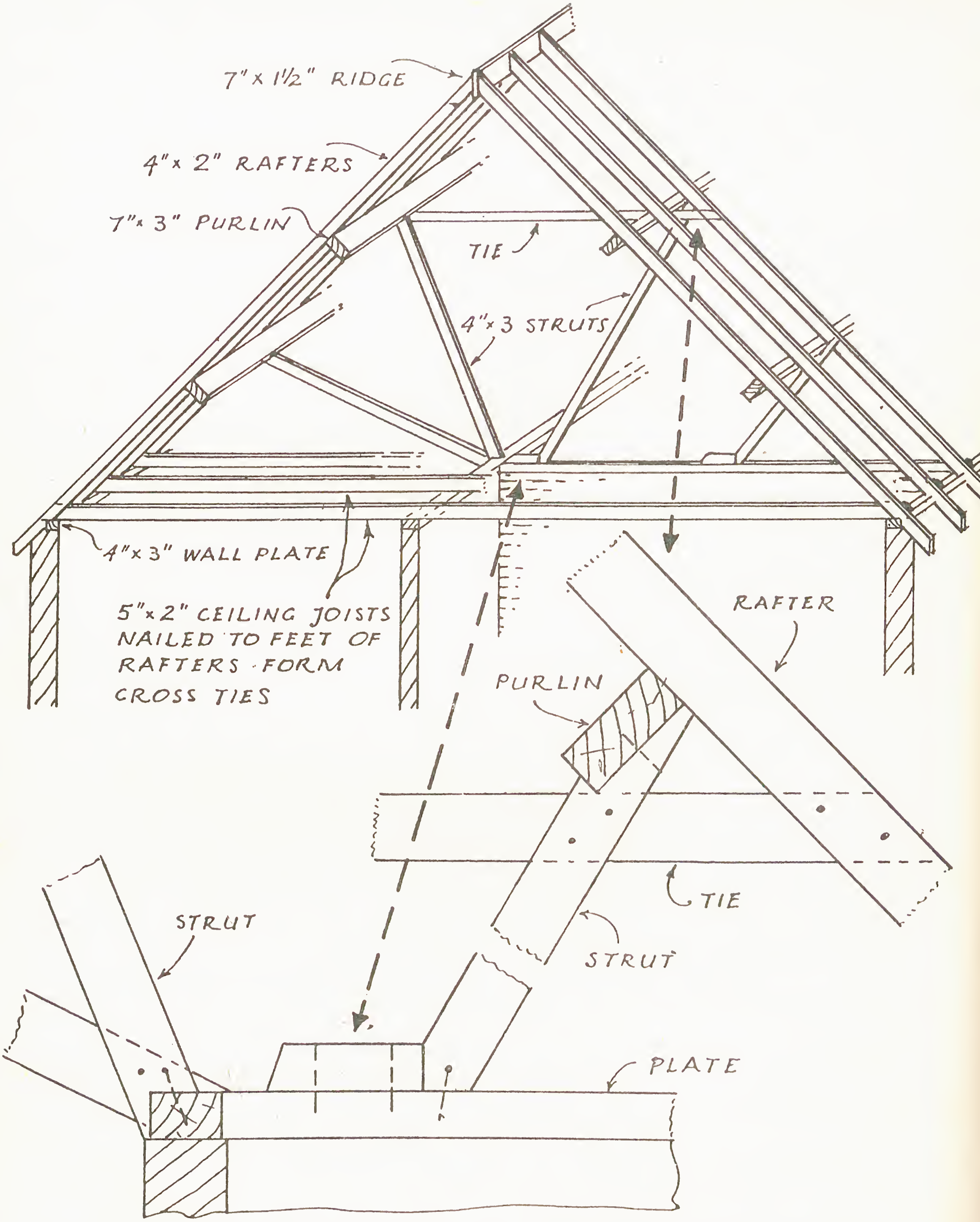


Fig. 59.—Typical house roof showing method of supporting purlins on struts. Alternatively, partition walls can be built up to support purlins.

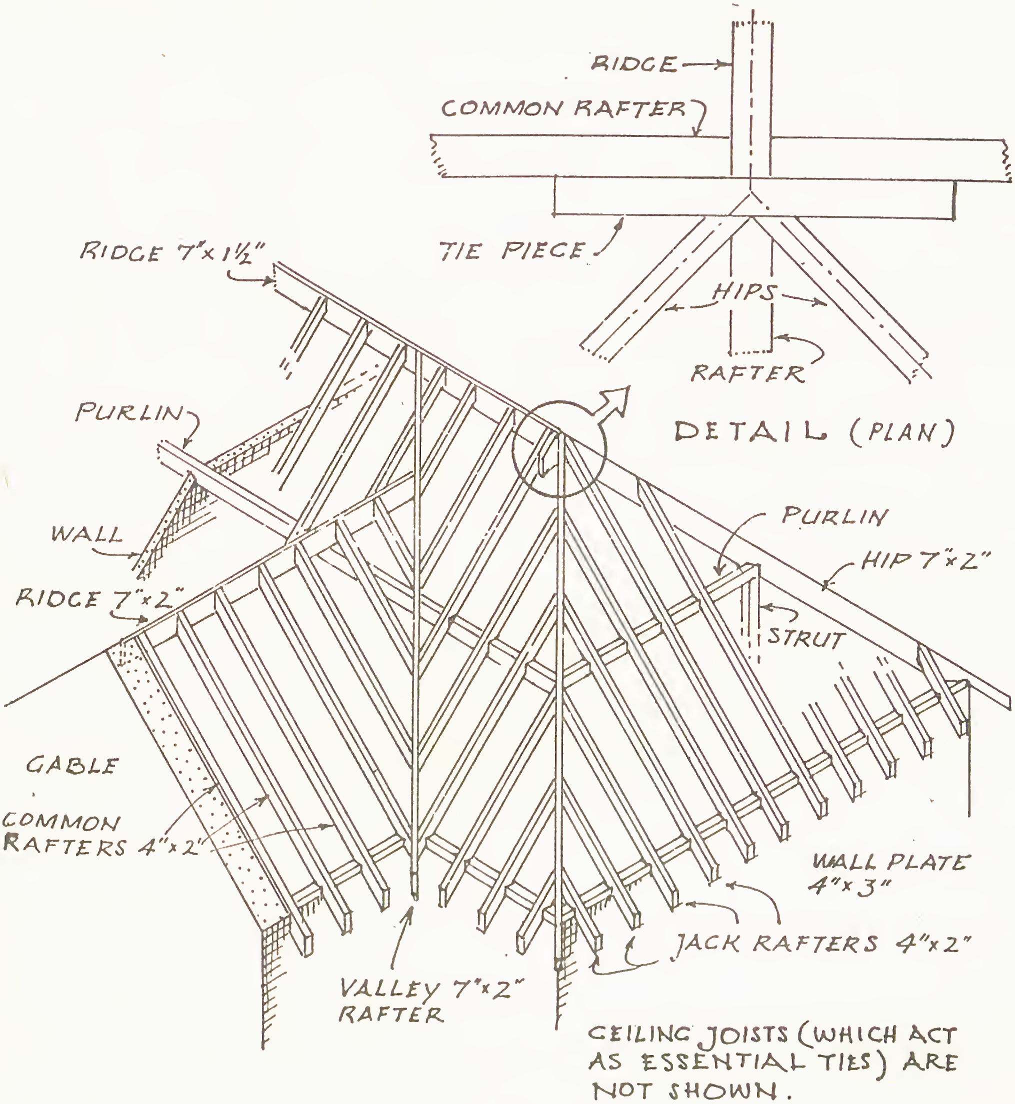


Fig. 60.—Typical hipped roof with secondary gabled roof and valley junction.

Hipped Roofs.—The hip rafters for small house roofs are usually 7 × 2 inches. With a central ridge the hips lie at 45 degrees on plan. A little consideration will show that the hip pitch is much lower than the rafter pitch.

The common rafters run from eaves to ridge. The shorter rafters which are trimmed to bevels against the hips are called Jack Rafters. They are nailed to the hips.

Purlins must be adequately supported on partition walls or struts.

Valleys.—Where one pitched roof joins another the intersecting lines are called valleys. The Jack rafters are bevelled against the valley

rafters and nailed, just as they are to the hips. Fig. 60 illustrates a hip and valley roof.

Small secondary roofs, such as dormer roofs, are sometimes joined to the main roof by using valley boards nailed to the surface of the main rafters. By this method there is no trimmed opening in the main roof rafters.

JOINTS USED IN SINGLE ROOFS

Bird's-mouth.—The joint at the feet of the rafters on to the inner top corner of the wall plate consists of two saw cuts forming an angle of the required shape to fit exactly on to the plate.

The Notch used when the rafters are continued past the plate, and also with the sprocket pieces, consists in a similar manner of two saw cuts on the underside of the rafters. This joint is also termed the Bird's-mouth Notch.

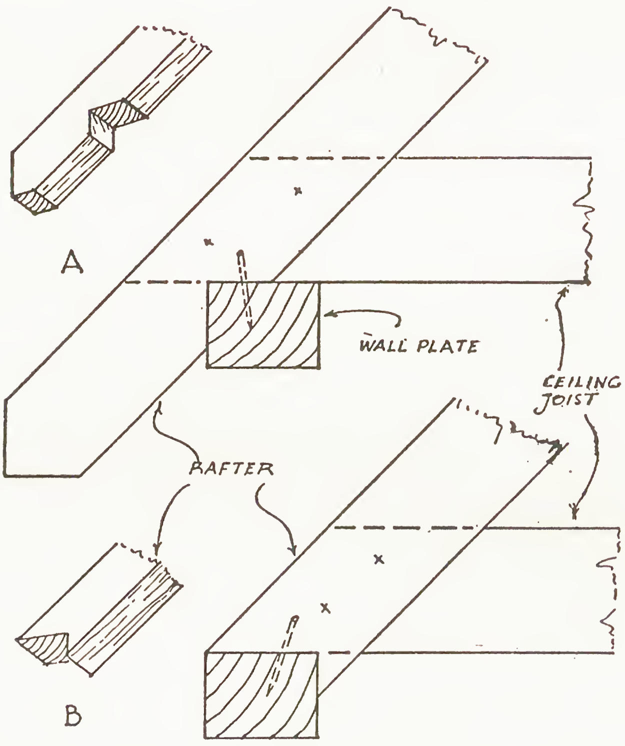


Fig. 61.—A. Foot of rafter overhanging, secured to wall plate with bird's-mouth notch. B. Bird's-mouth at foot of rafter.

The Notched Strut is one where the rafters are carried past the plate and the plate is required to be at a lower level and on the inside of the wall for another purpose, such as for fixing ceiling joists to a short length of strut. This is mortised into the plate, having its upper end shaped to fit into the bird's-mouth notch. This last, however forms a weak joint, its strength being that of the tenon. A simpler and hardly more expensive method is to build in a second wall plate at the required height.

Rafters to Ridge.—The top ends of the rafters are splay cut to form a bevelled joint and nailed.

Collar to Rafters.—Where the rafters are cut away for the collars, both form a halved dovetail joint. However, it is generally thought inadvisable to cut any of the timber away from the rafter in its length, and a sufficiently strong connection between the collars and rafter is afforded by halving the collar only and nailing. It would be a much stronger job to bolt the collars to the rafters than to cut the rafters for halving.

End Rafters, where exposed to give a finish to the gable and to carry the verges, are wrought and increased in size. Where the ordinary rafters are 4 × 3 inches, the end rafters are wrought out of 5 × 3 inches. The inner top corner is notched for the ends of the battens.

Rafters against Vertical Brickwork, such as a chimney stack, are bird's-mouth notched on to a $4\frac{1}{2} \times 3$-inch wall plate, supported on 4-inch wrought-iron corbel brackets built into the brickwork.

Battens to Rafters.—The battens are laid on the tops of the rafters and nailed thereto at distances apart required by the gauge. Where the eaves are required to show a boarded face the tilting fillet may be formed of a feather-edged board laid with the thick edges downwards.

Ridge to End Rafters.—The end of the ridge may be jointed to the end wrought rafters either by a notched joint, the notch being cut in the two upper corners of the bevelled rafters and a tongue cut on the top edge of the end of the ridge to fit into this notch, or alternatively the notch may be carried through the thickness of the wrought rafter and the tongue cut long enough to fit, when the joint becomes a rebated joint.

DOUBLE ROOFS

The tie in a single-span roof, if the span is wider than the distance given, would not only require to be of a timber so large as to be uneconomic but also it would have a tendency to sag at its centre due to its own weight.

To avoid this last an iron rod, known as a *King Rod,* is suspended from the ridge and bolted through the centre of the tie beam, being fitted with an adjustable screw and nut.

Above the spans given, however, it is considered advisable to introduce a truss which not only overcomes the last difficulty mentioned, but also gives support to the rafters, which, owing to their length, would tend to sag under the pressure of the roofing material above them added to their own weight.

This additional support is given in the first place by *Purlins,* which are squared timbers run from end wall to end wall where possible, or from end wall to hip, and the trusses become necessary when the span is increased and the sizes of the purlins required become too great to be satisfactorily self-suporting in their lengths.

Additional Support to purlins in their lengths is given by carrying up the partitions wherever possible and necessary or by introducing special upright struts. The struts are stood on base plates at their feet and folding wedges are driven in to tighten them up.

The purlins are placed with their greater dimension vertical, so that the studs or braces, generally 4 × 4 inches, are butted against the horizontal face offered by their under surfaces.

The rafters are bird's-mouthed over the outer top corner of the purlin and nailed through their sides to the purlin.

Joints in the Length of a Purlin are made, when necessary, with the scarfed joint, though it is preferable, and should generally be possible, to secure timbers in single lengths for purlins in most ordinary types of buildings. Where the scarfed joint is used a strut should be introduced to give additional support to the purlin at this joint.

Joints in the length of a Ridge are also scarfed.

Trimming round Chimneys and Openings.—Trimming of roof timbers is much the same as that to floors, though the joints used are different. The rafters at the sides of the opening are called the *Trimming* rafters, and where the ordinary rafters are $5 \times 2\frac{1}{2}$ inches the trimming rafter will require to be 5×3 inches. Across the opening is let in a *Trimmer* rafter 5×3 inches to take the ends of the intermediate or *Trimmed* rafters $5 \times 2\frac{1}{2}$ inches.

The Joint between the trimmer and the trimming rafters is a pinned tenon, the tongue of the tenon having its breadth parallel with the upper or narrow face, and the pin being driven in through a hole cut to receive it in the projecting tenon.

A Dovetail Chase is cut in the upper side of the trimmer rafter and into this are slid downwards the ends of the trimmed rafters.

The trimming rafters are carried down to the 4×3-inch wall plate in the same way as the ordinary rafters and bird's-mouthed thereon.

Ceilings are carried on 4×2-inch ceiling joists, and where the span requires it, ceiling bearers 7×4 inches are run across at right angles to the ceiling joists, and into notches cut into the bearers the joists are nailed sideways from underneath.

Dormer Windows.—The openings for dormer windows are trimmed similarly, though the sizes of the trimmer and the joints are different, as being on the splay in the roof, *i.e.* upright, they require to be deeper in proportion to take the splay cut on the trimmed rafters. In a roof of which the ordinary rafters are 6×2 inches the sill trimmer, *i.e.* the one at the lower end of the opening, will require to be about 9×4 inches and the upper one 7×3 inches. Frequently, in cheaper work, these two trimmers consist of double rafters simply butted and nailed to the trimming rafter, which should be 1 inch wider than the ordinary rafters. But this construction is not good, and in better work special joints are cut, that on the upper trimmer being a tenon on the diagonal, parallel to the upper face of the rafters, the trimmer itself being vertical, it is understood. The joint between the lower trimmer and the trimming rafter is a special form of halving with an oblique shoulder, the upper surface of which is tenoned for a stub tenon on the corner upright to the dormer. These corner posts in cheaper work are generally two 4×2 inches run from a plate 4×2 inches laid over the floor joists: and the space under the lower trimmer between these corner posts and the space at the side or cheek of the dormer is framed with 3×2-inch upright studs, also called ashlaring, which is another example of the use of the same word for

entirely different forms of construction—the other use, in this instance, being masonry.

Framing the roof of the dormer for a flat top, over the tops of these upright studs is run a 3 × 3-inch head which supports 4 × 2-inch joists run parallel with the trimmers. Alternatively the joists are fixed to the face of the trimmer and run over a head at the front over the dormer composed of two 4 × 2-inch studs laid across the corner posts. Over either form of flat top 6 × 1-inch boarding is nailed.

Dormers with Gable Roofs are trimmed for in the same manner, but the plate at the sides over the 3 × 2-inch upright studs are formed of 4 × 3 inches or two 2 × 3 inches nailed together. Over these rafters are bird's-mouthed similarly to those of the main roof. A short ridge is formed between this apex and nailed at its inner end to a rafter or to a bearer between the rafters. Alternatively the upper trimmer is replaced by two hipped trimmers splay jointed at the top where they come together.

A Hipped Dormer is framed similarly, with the exception that the ridge is terminated at the point where the two front hips meet. For illustrations see Vol. II, Chapter 12.

Hips are constructed in the following manner: as considerably more weight is carried down by the hip than the ordinary rafters, some additional support at foot is required. Consequently, a triangular formation known as a *Dragon Tie* is devised, having the purpose of spreading this load. This consists of an angle tie 6 × 3 inches run across the corner from wall plate to wall plate, being dovetail notched thereto at each end, and from the centre of this angle tie the 6 × 3-inch *Dragon Beam* is run to the junction of the halved wall plates. The joint between the dragon beam and the angle tie is a horizontal tongued tenon and that between the dragon beam and the wall halved plates consists of a notch with V-shaped shoulders to fit the right angle formed by the plates.

On the upper face of the dragon beam is cut a mortise with a bevelled bottom to take the tenon cut with a shoulder on the hip rafter, which should be about 11 × 2 inches in an ordinary roof. The foot of the hip is also bored for a $\frac{1}{8}$-inch bolt securing it to the dragon beam.

Jack Rafters are cut in short lengths to run from the plate to the hip to which they are nailed with splayed joints.

Valleys are formed in a similar manner to hips, the jack rafters running from valley rafter to ridge, instead of to the wall plates, and the angle formed being reversed.

Joints between Hip and Valley Rafters and Purlins.—In roofs having purlins they are splay cut against the sides of the hip and nailed, or alternatively the purlin ends are cut with splayed notches on the top edge to the correct bevel and of a depth of half the thickness of the hip or valley rafter. The lower portions of the purlins are continued under the hip or

valley and splayed. The three timbers are bolted together with a ½-inch bolt.

Trimming for Skylights is constructed of trimmers similar to those for a chimney opening, but in this instance there are two at each end of the opening. On these a further framing is constructed, having a 7 × 2-inch kerb run round to take the side framings supplied with the skylight-glazed sash and frame.

MODERN TIMBER TRUSSES

Modern timber trusses are designed in a similar manner to steel trusses. The stresses are investigated and the trusses designed to carry the load on the minimum amount of material.

The traditional joints, as used in the older King and Queen post trusses, are rarely used as they are wasteful of material and do not fully develop the safe working stress. They are also costly to make.

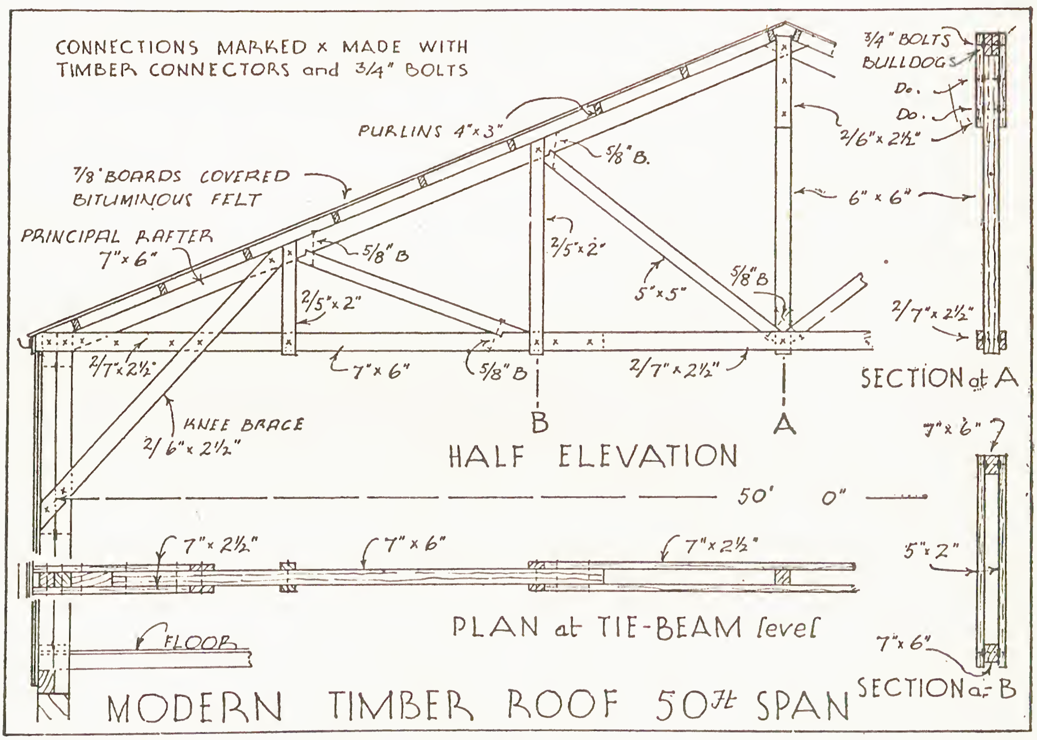


Fig. 62.—Modern timber truss, sandwich construction, joints made with timber connectors and bolts.

Sandwich Construction.—Trusses can be economically constructed of light timber sections by sandwiching single members at their ends between double members and securing the joints by bolting, either with or without timber connectors. In light trusses nails are sometimes used instead of bolts.

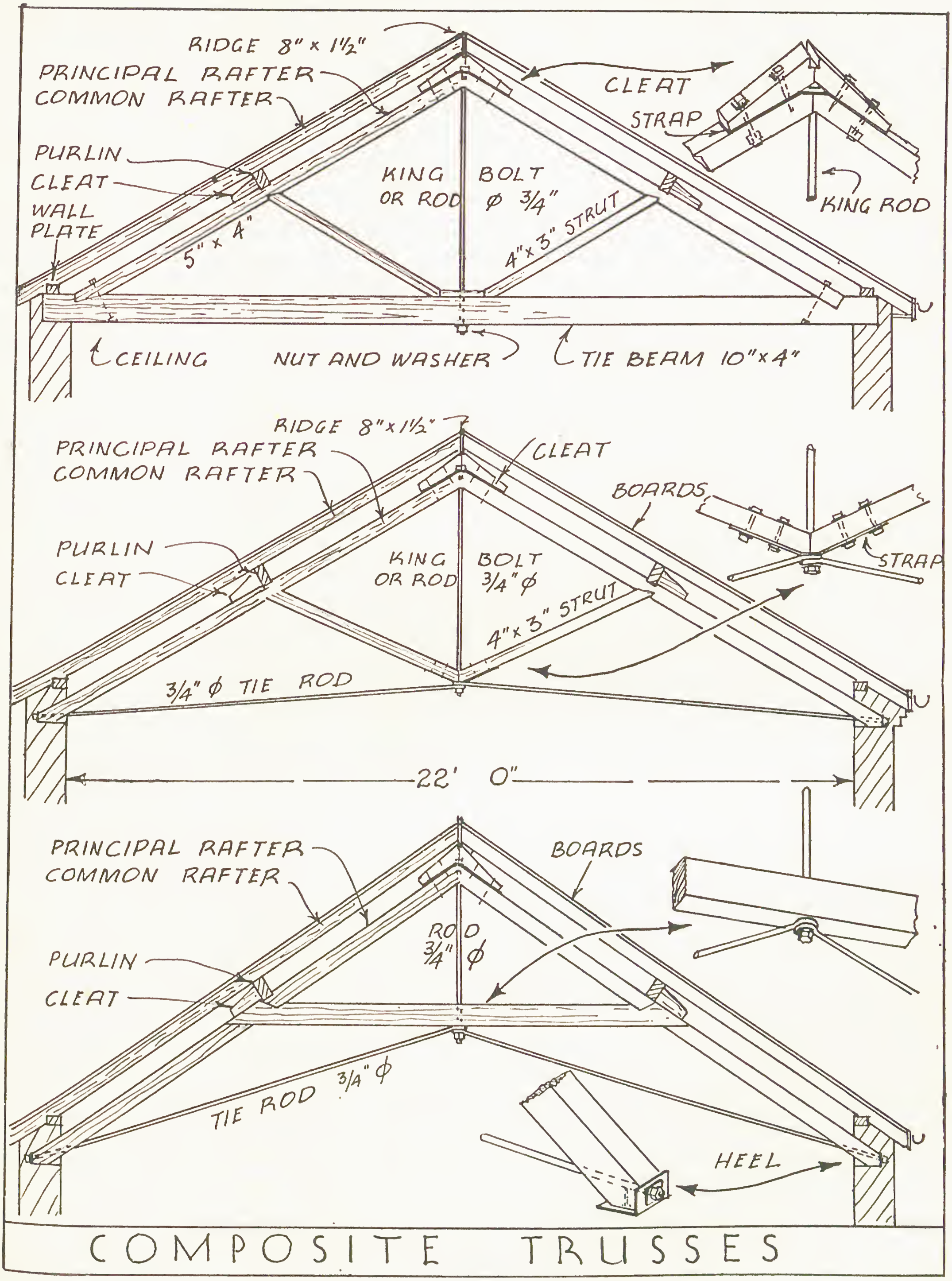


Fig. 63.—Steel rods are used as tension members in these trusses.

Timber Connectors.—The older mortise and tenon and other cut joints are weak in shear and tension and tend to concentrate the stress on small areas of material. The plain bolted joints also concentrate the stress. The metal timber connector, used in conjunction with the bolt, distributes the stress, enables accurate calculations to be made of the strength of a joint, and effects considerable economy in timber. The joint is more simply and quickly made than a mortise and tenon or other cut joint. See Fig. 41, Chapter 3.

Thus, no timber is wasted as the full working load of the material can be developed. In the average case the saving of timber by using connectors is about 35 per cent.

Example.—A modern timber roof of 50-feet span is illustrated in Fig. 62. This has been designed for joints made with $\frac{3}{4}$-inch bolts and 4×4-inch square "bulldog" connectors—a toothed type which bites into the wood when the bolt is tightened If bolts were used without connectors the timber members would have to be of larger sections to accommodate the extra bolts required to give safe stress distribution in the joints. An interesting feature of this design is that the tie beam is built up of rather short lengths of timber.

Composite Truss.—These are of two types: those framed by ordinary joints, and those framed with timber connectors and bolts.

Three examples of the first type are illustrated in Fig. 63. In composite trusses steel rods are used as tension members. The vertical rod in the centre is called the King bolt. Rods can also be used as ties instead of timber tie beams.

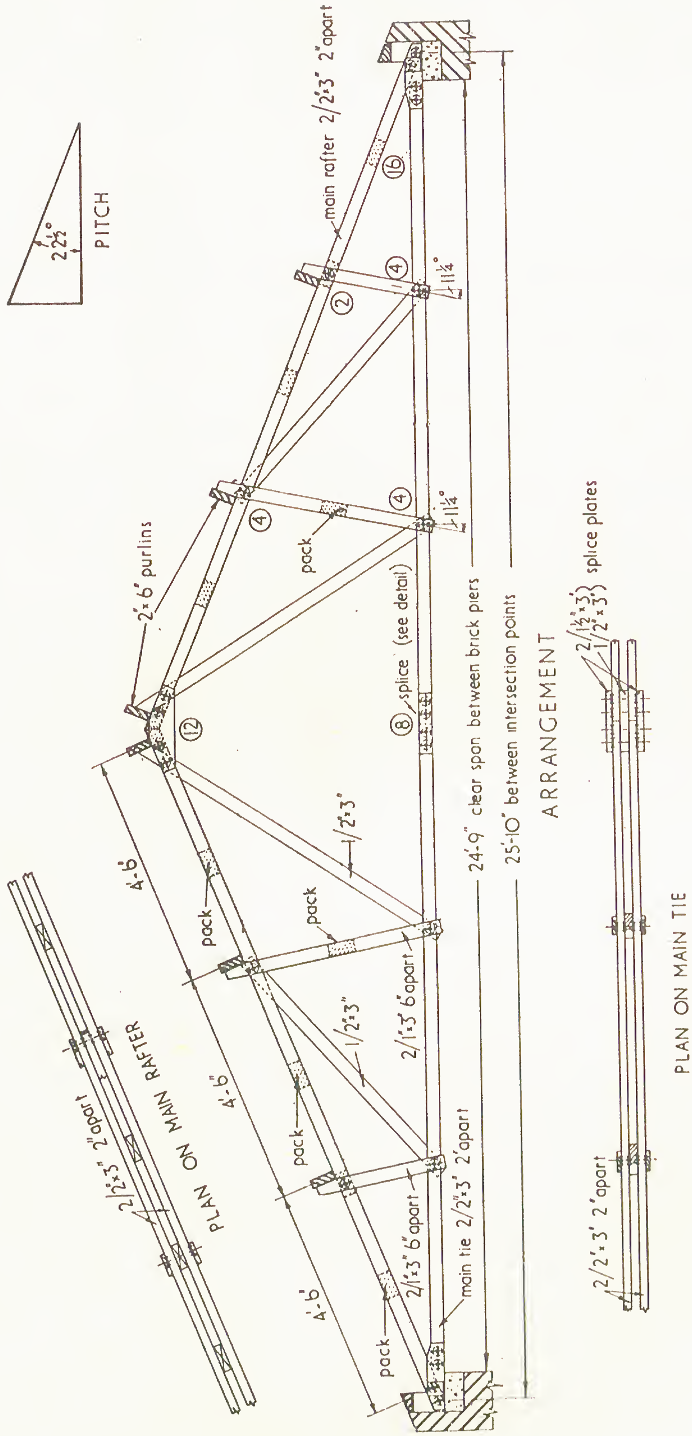
Fig. 66 illustrates a modern composite truss 65 feet 6 inches span, certain of the joints being made with "bulldog" connectors. Struts are solid timbers, principal rafters are solid spliced timbers, and the tie beam is built up on the sandwich method.

Belfast Truss.—This is an economical type of truss using material of small section with nailed joints. The shape is that of a bow-strung girder which is a close approximation to the bending moment diagram for evenly distributed load and is therefore economical.

The curved bow is a laminated member consisting of four individual sections, two $1\frac{1}{2} \times 1\frac{1}{2}$ inches on each side of the lattice bars, which are 3×1 inch. As these bars cross between the tie beam and the bow it is necessary to use a packing piece with the end of the bar where it is sandwiched between bow or tie beam. The tie beam consists of two $9 \times \frac{3}{4}$-inch boards on each side. The ends of the bow are anchored to the tie beam by gusset boards and a steel strap.

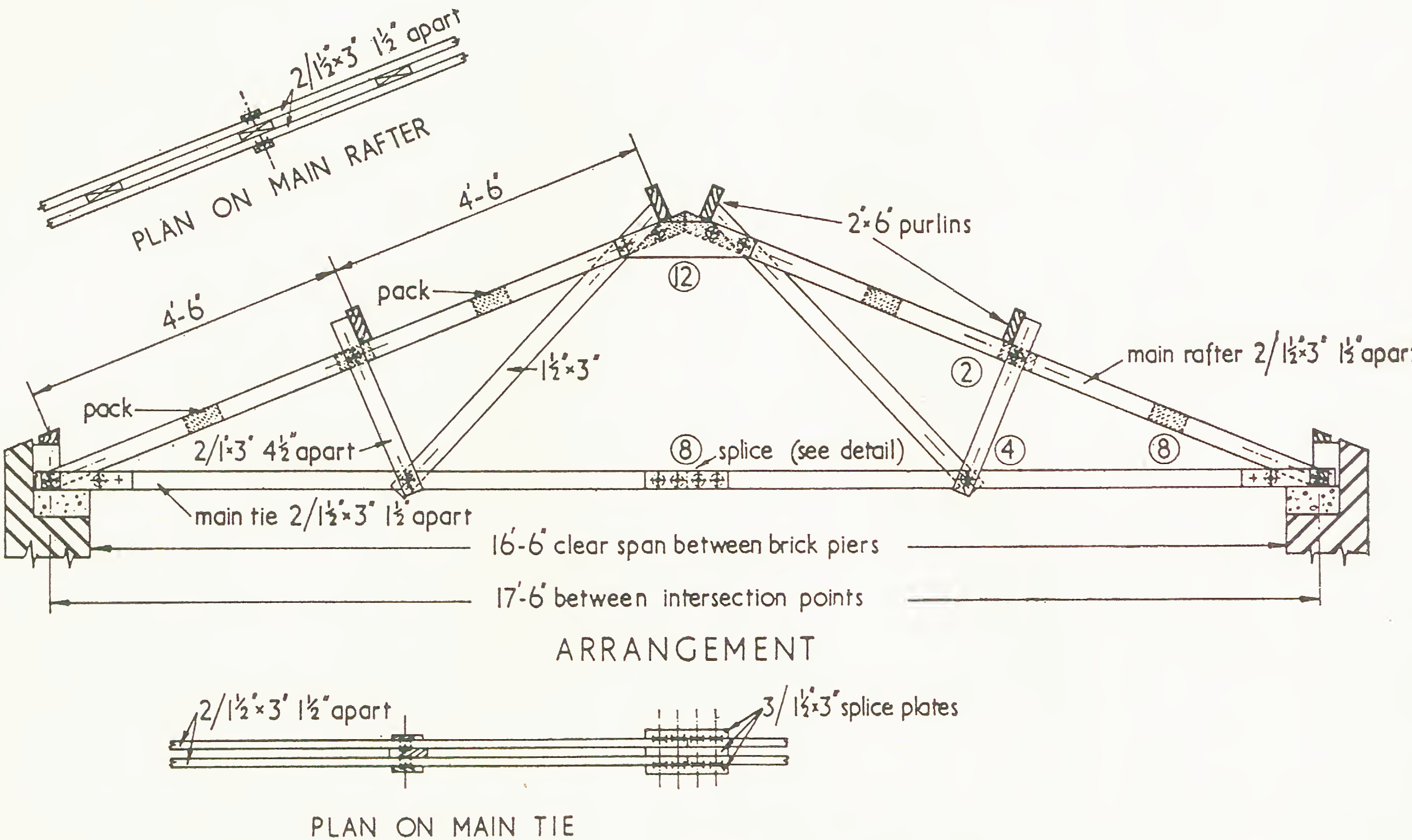
A number of firms throughout the country make Belfast trusses at such low prices that it does not usually pay a builder to make them specially.

A table of sizes of members for various spans is given at the end of this chapter, and an example is illustrated in Fig. 67.



PITCH
$22\frac{1}{2}°$
main rafter 2/2"x3" 2"apart
2"x6" purlins
pack
splice (see detail)
$11\frac{1}{4}°$
4'-6"
1/2"x3"
2/1"x3" 6"apart
main tie 2/2"x3" 2"apart
PLAN ON MAIN RAFTER
2/2"x3" 2"apart
24'-9" clear span between brick piers
25'-10" between intersection points
ARRANGEMENT
2/1½"x3"
1/2"x3"
splice plates
PLAN ON MAIN TIE
2/2"x3" 2"apart

Fig. 64



PLAN ON MAIN RAFTER
2/1½"×3" 1½" apart
4'-6"
4'-6"
pack
pack
2/1"×3" 4½" apart
1½"×3"
12
2"×6" purlins
main rafter 2/1½"×3" 1½" apart
2
4
8
8
splice (see detail)
main tie 2/1½"×3" 1½" apart
16'-6" clear span between brick piers
17'-6" between intersection points
ARRANGEMENT
2/1½"×3" 1½" apart
3/1½"×3" splice plates
PLAN ON MAIN TIE

Fig. 65

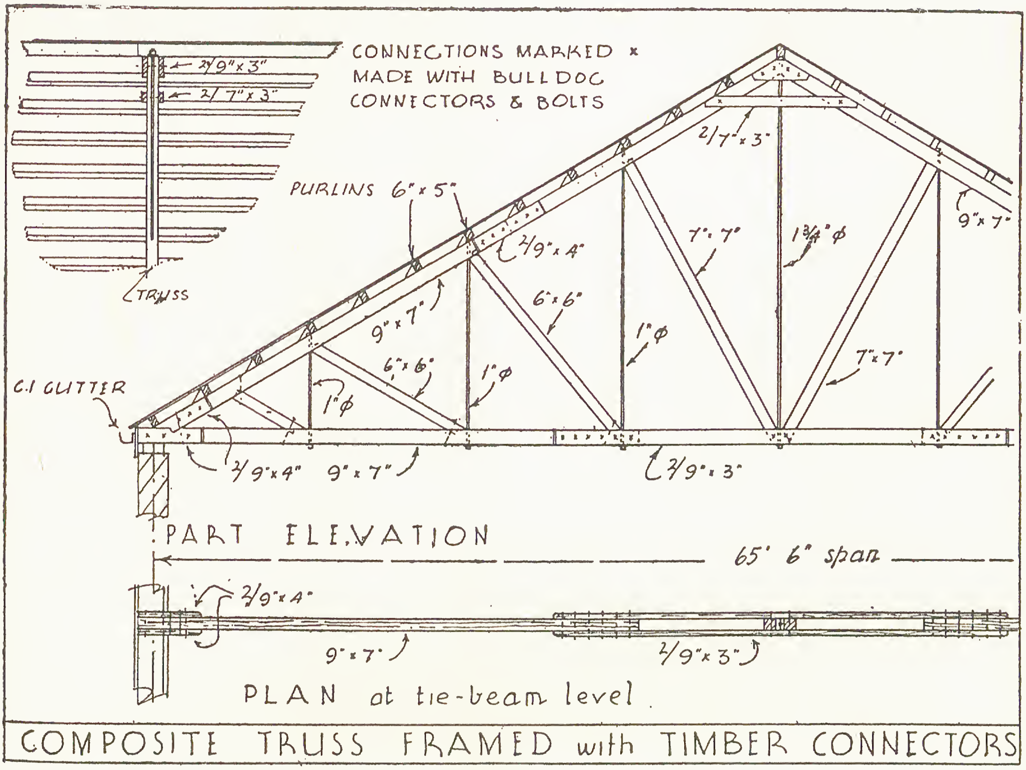


Fig. 66.

Other modern wood-framed trusses are specially designed for individual jobs. As they are designed scientifically for the most economical use of the material it is impossible to give simple empirical rules for selecting sizes of members according to span, and such sizes should certainly not be arrived at by guesswork.

TRUSSED ROOFS

The King and Queen Post Trusses.—For spans over 20 feet, some additional support is required than that afforded by the collar beam roof with purlins or by the King rod roof. Consequently, trusses are employed at distances of about 10 feet along the length of the roof, *i.e.* in the direction of the ridge and across the span to support the purlins which in their turn support the common rafters.

This additional support to roofs spanning a larger distance is rendered necessary not only by the increased weight of the roof materials, but also on account of the larger area exposed to wind pressure and from the weight of snow which may collect; and as the point at which the main need for such support is felt is at the centre of the span of each length of rafter, *i.e.* halfway between the ridge and wall plate, and this, as has been

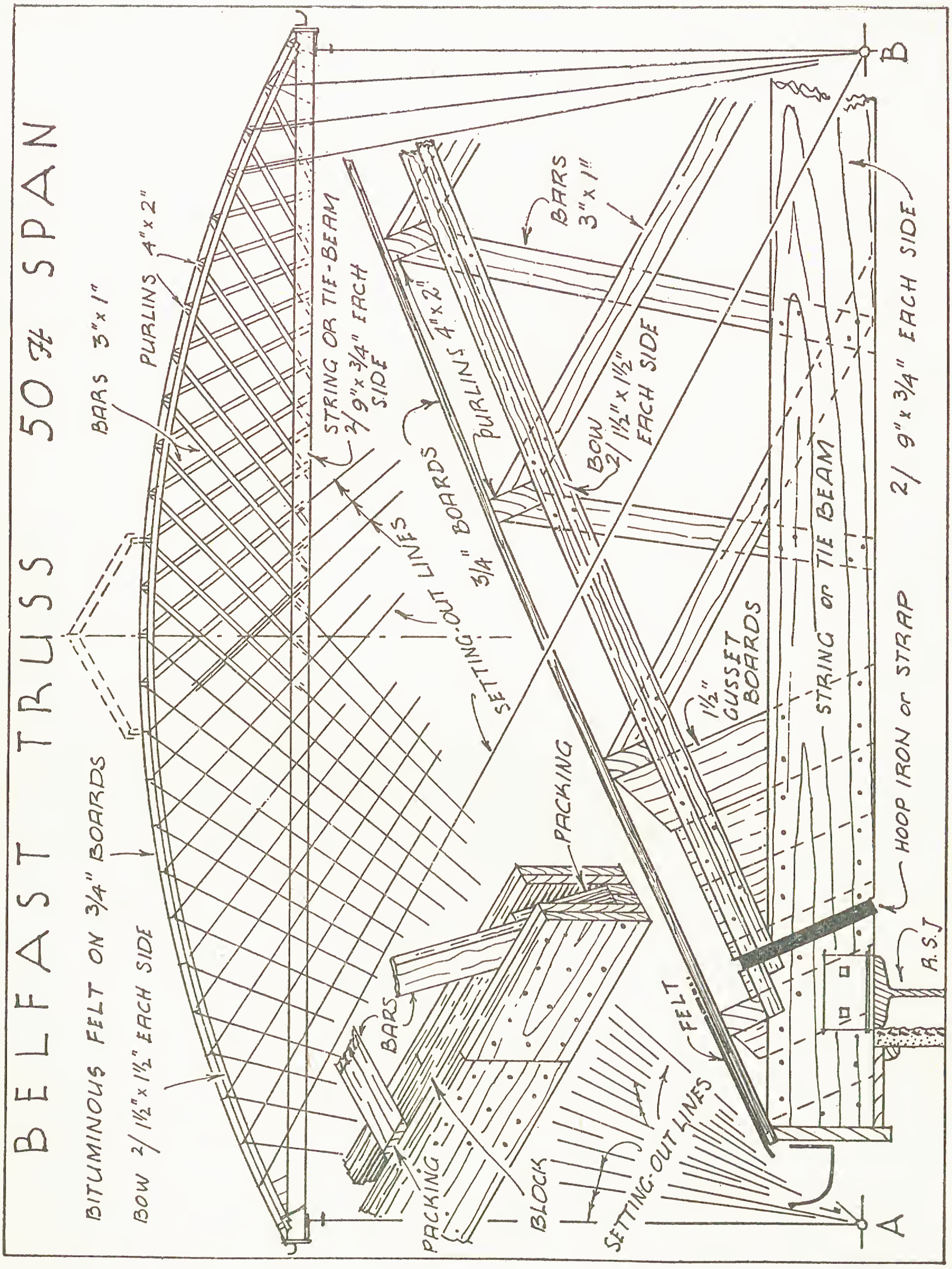

BELFAST TRUSS 50 FT SPAN
BITUMINOUS FELT ON 3/4" BOARDS
BOW 2/ 1½" x 1½" EACH SIDE
BARS 3" x 1"
PURLINS 4" x 2"
STRING OR TIE-BEAM 2/ 9" x 3/4" EACH SIDE
SETTING-OUT LINES
3/4" BOARDS
PURLINS 4" x 2"
BOW 2/ 1½" x 1½" EACH SIDE
BARS 3" x 1"
1½" GUSSET BOARDS
STRING or TIE BEAM
2/ 9" x 3/4" EACH SIDE
HOOP IRON or STRAP
R.S.J
PACKING
BARS
FELT
PACKING
BLOCK
SETTING-OUT LINES
A
B

Fig. 67.

explained, is the point at which the purlins are introduced, so in the King and Queen post trusses direct support is given to the purlins at that point. In the King post truss this is supplied by Braces or Struts run diagonally from the foot of the central King post; and in the Queen post truss, the Queen posts themselves are placed vertically under the purlins.

Spans.—The King post truss is suitable *for spans up to* 30 *feet,* and the ordinary Queen post for *spans up to* 45 *feet.* For spans above 45 feet a strengthened Queen post truss having additional supports known as Princesses, and the truss being termed Queen post with Princess truss, is used.

For spans over 50 *feet* a combination of King post truss and Queen post truss is employed, the King post truss being introduced to give support to the ridge and the straining beam (see below) of the Queen post truss.

For spans over 60 *feet* the matter passes beyond the province of the carpenter and becomes that more rightly belonging to the engineer who uses steel in the construction of the necessary trusses.

The King Post Truss for a span of 20 feet consists of:

Two principal rafters 4 × 4 inches termed *the Principals,* tied in at their feet by

A Tie Beam about $9\frac{1}{2} \times 4$ inches supported at its centre by

The King Post, cut out of 7 × 4-inch splay with shouldered head and foot to 4 inches square in its main length, strapped and jointed to the tie beam and strapped and jointed to the principals, and also carrying the ridge board of the common rafters. The king post is a tension member, hence the importance of the straps.

The Struts, 4 × 3 inches, are run from the splay-shouldered foot of the King post to a point centrally under the *Purlin,* 8 × 4 inches, which is placed centrally in the length of the principal.

Details.—Without going in any way deeply into the mechanics of the subject, the effect of the weight of the roof on the various members and the stresses which they are constructed to resist should be understood, as these naturally have an effect on the formation of the joints. Shortly put, these are as follows: the tie beam and King post are in tension, *i.e.* pulling forces; and the principles and struts in compression, *i.e.* pressed together. Whilst it is easy to consider the tie beam as in tension owing to the spreading action of the principals, it is not always so readily understood how the King post can be subjected to the same pulling strain. The point is that the King post supports the tie beam at its bottom end, and the tie beam, by its resistance to the spreading tendency of the principals, compresses them, with the result that this pressure is communicated to the head of the King post, tending to pull it upwards. So that we have one force at the foot of the King post tending to pull it downwards, *i.e.* the weight of the tie beam, and another at its head tending to push it upwards, *i.e.* the pressure of the principals. Consequently, the King post is in tension.

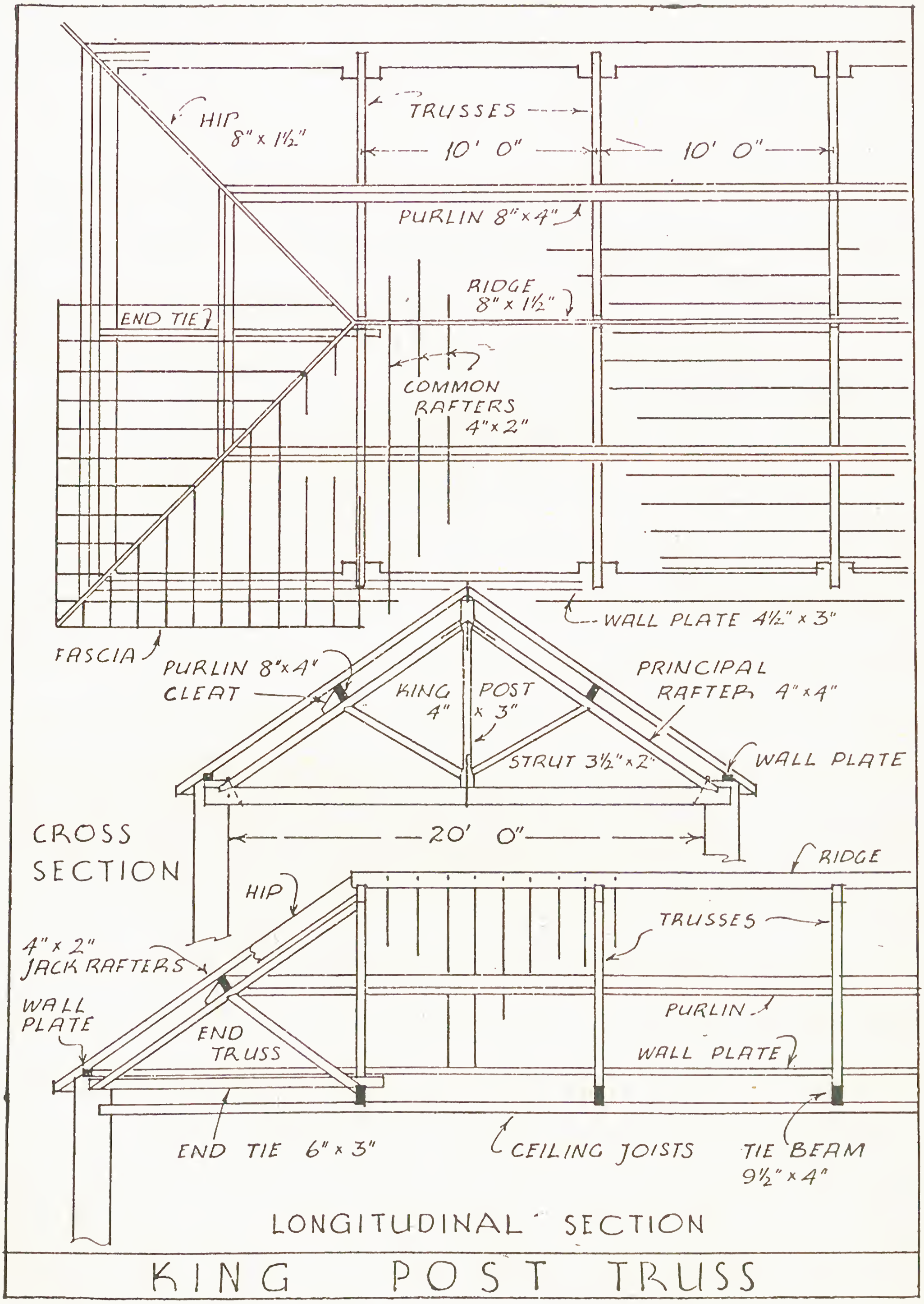

HIP 8" x 1½"
TRUSSES
10' 0"
10' 0"
PURLIN 8" x 4"
RIDGE 8" x 1½"
END TIE
COMMON RAFTERS 4" x 2"
WALL PLATE 4½" x 3"
FASCIA
PURLIN 8" x 4"
CLEAT
KING POST 4" x 3"
PRINCIPAL RAFTER 4" x 4"
STRUT 3½" x 2"
WALL PLATE
CROSS SECTION
20' 0"
RIDGE
HIP
4" x 2" JACK RAFTERS
TRUSSES
WALL PLATE
PURLIN
END TRUSS
WALL PLATE
END TIE 6" x 3"
CEILING JOISTS
TIE BEAM 9½" x 4"
LONGITUDINAL SECTION
KING POST TRUSS

Fig. 68.

The Head of the King Post, 7 × 4 inches, the wider dimension being on the face, is jointed at its upper end to the ridge 10 × 2 inches by a groove into which the lower side of the ridge is let. Below this are two splayed shoulders diminishing the face from 7 inches wide to 4 inches, and so reducing the post to 4 × 3 inches. In these splayed shoulders on the side faces are cut mortises to receive the abutment tenons cut on the top ends of the principal rafters 7 × 4 inches.

Metal Strap.—These three timbers are held together by a three-way wrought-iron strap with arms about 14 inches long and each arm bolted with two ½-inch bolts, another bolt being inserted at the junctions of the three arms.

The splayed shoulders to the King post are sometimes replaced by a double abutment V-shaped shoulder as an alternative method, but it is open to doubt if the extra work justifies expense in cutting.

Foot of King Post.—In a like manner, only reversed, the foot is widened out to the 7 inches of face with a splayed shoulder to receive the feet of the 3½ × 3-inch struts, which are tenoned into the mortise cut in the splay.

The King post is tenoned into the tie beam 11 × 4 inches with a plain mortise and tenon joint, and a mortise is cut through the post from front to back above the splayed shoulder to take the fastening for the wrought-iron strap.

Metal Strap.—This is of the stirrup type, and is run from the mortise mentioned above round the tie beam, and is wedged up tight so as to pull the tie beam up to the shoulders of the King post tenon by a combination of metal wedges known as *Gibs and Cotters*. The dimensions of this strap are 2 feet 6 inches × 2 feet × ¼ inch.

Principal Rafter and Tie Beam.—The joint at the foot of the principal rafter and the tie beam is either a bridle joint or an abutment and tenon joint, the tenon being cut on the principal rafter and the abutment at its end being square with the line of its direction. The tie beam is continued for about 6 inches in its length past the point of intersection of the centre line with the centre line of the tie beam. On the under surface of the tie beam a splayed notch is cut for the reception of the wrought-iron strap which binds this joint.

Metal Strap.—The strap which binds this joint is 1½ × ¼ inch of wrought-iron and termed a *Heel Strap*. It is rounded out at its bottom end at a point over the centre line of the tie beam and pierced with a hole to receive a ¾-inch bolt, which is passed through the tie beam and secured on the other side, fastening the other end of the strap with a nut. Or, alternatively, the strap is run completely round the joint and fitted at the underside of the tie beam into the splayed notch mentioned above. This strip is in two pieces, having a 7 × 4 × ⅜-inch metal plate at the top pierced with two holes to take the two rounded ends of the strap which are cut with a screw worm to take the nuts.

Struts and Principal Rafters.—The joint between these timbers may be either a shouldered mortise and tenon with the tenon cut on the strut and the end of the strut cut with V-shaped shoulders, or, it may consist of a

simple splayed mortise and tenon, sometimes termed an oblique mortise and tenon. On the upper face of the principal rafter a wide groove or cogging is cut to receive the purlin, which is secured additionally by a cleat $9 \times 4 \times 4$ inches, which may also be tongued and let into a groove in the principal rafter as an additional precaution against slipping.

Common Rafter or Ridge, Purlin, and Wall Plate.—The common rafters are splayed and nailed to the side of the ridge, cogged over the purlins, and bird's-mouthed on to the wall plates.

The feet of the rafters may terminate in an eaves, or they may end under a gutter behind a parapet wall.

Eaves Finish.—When finished as an eaves having a gutter fixed to a fascia board run along the ends of the rafters, the rafters are bird's-mouth-notched over and continued past the pole plate. Or alternatively, they may be stopped on the pole plate in a bird's-mouth cut in their ends, when sprocket pieces are fixed to their sides and to the ends of these the fascia and gutter are fixed. If a wood cornice is required at the rafter ends, they are boxed in by the fascia and a soffit, mouldings being affixed, the gutter forming the top member of the cornice.

An Alternative Method of finishing the eaves is to situate the pole plate on the projecting end of the tie beam, running the common rafters over and past this, and to nail to the side of the rafter feet bearers, known as *Planceer Pieces*, run back and fixed to the wall plate and to the sides of the tie beams where these coincide.

Parapet and Gutter Finish.—To give support to the feet of the rafter when there is required to be a gutter behind a parapet wall, a pole plate 9×3 inches is introduced, being bracketed to the principal rafters on their upper faces, and on to the top inner corner of this the ends of the common rafters are finished in a bird's-mouth.

The gutter is framed on a 6×2-inch bearer run parallel with the wall and alongside it, and short cross bearers 4×2 inches are notched over this at one end, and nailed, or in better-class work, tenoned, to the pole plate at the other end. Over these 1-inch thick gutter boards are nailed, with their length run down the length of the gutter.

Roof Boarding.—This is nailed to the common rafters to receive the battens on to which the tiles or slates are hung. It is laid parallel with the ridge, and should be covered with felt as described in Roofing (Chapters 11, 12, and 13 of Vol. II).

***Queen Post Truss.**—Span.*—As has been said, when the span exceeds 30 feet, a Queen post truss is formed and built in at every 10 feet in the length of the ridge. This type of truss, having a space in place of the central or King post replaced by two uprights known as Queen posts, also serves the additional purpose of enabling the space between them, in the roof, to be utilised for habitable rooms.

The main feature of the Queen post truss is the *Straining Beam* which keeps the heads of the Queen posts apart.

The mechanics of the matter lies in the strain of tension contributed

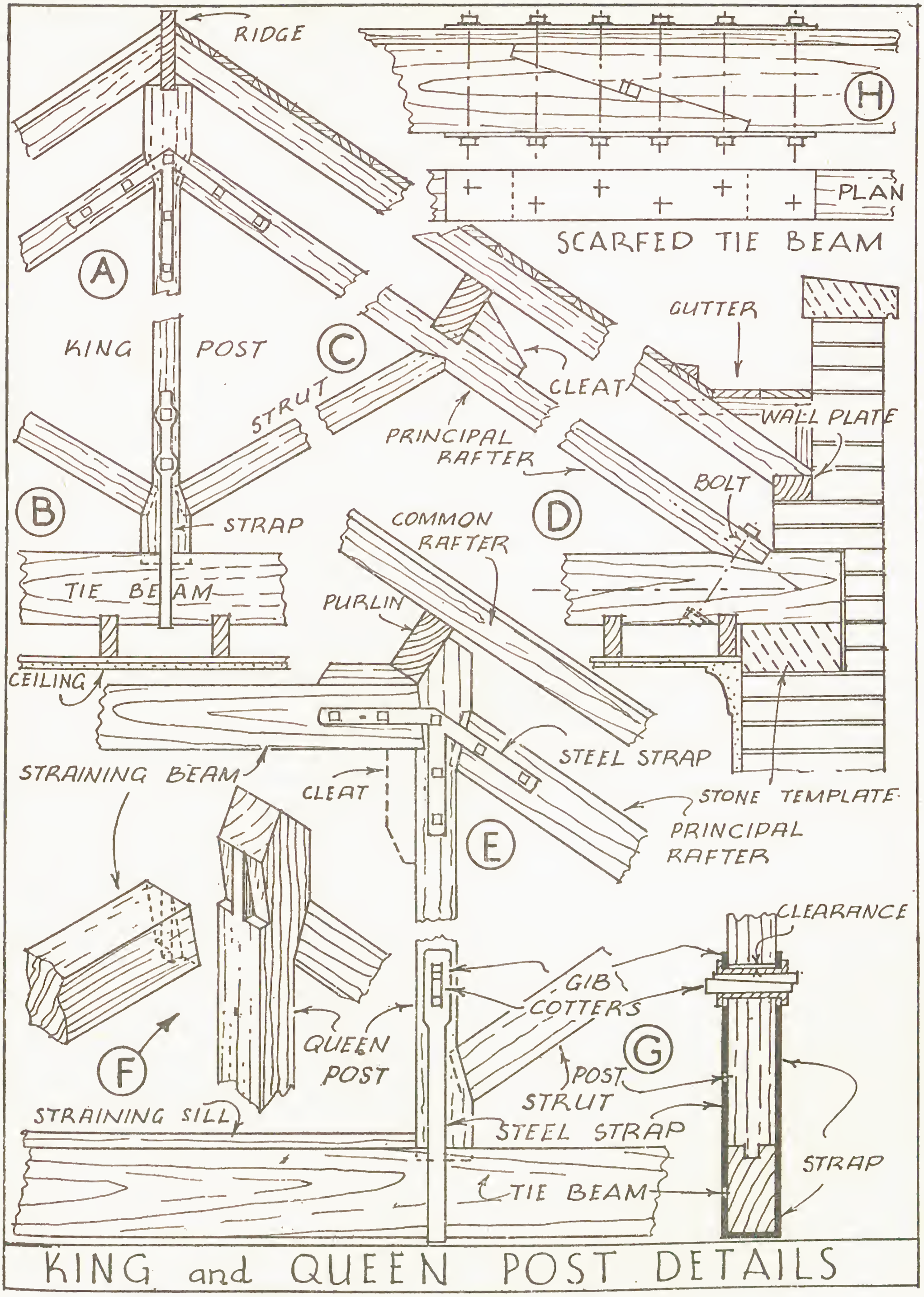

RIDGE
A
KING POST
STRUT
C
CLEAT
PRINCIPAL RAFTER
B
STRAP
TIE BEAM
CEILING
H
PLAN
SCARFED TIE BEAM
GUTTER
WALL PLATE
BOLT
D
COMMON RAFTER
PURLIN
STEEL STRAP
STRAINING BEAM
CLEAT
E
STONE TEMPLATE
PRINCIPAL RAFTER
CLEARANCE
GIB
COTTERS
QUEEN POST
F
G
POST STRUT
STRAINING SILL
STEEL STRAP
TIE BEAM
STRAP
KING and QUEEN POST DETAILS

Fig. 69.

to the tie beam by the tendency to spread of the rafters; but as the principal rafters are not continued past the heads of the Queen posts, and the weight of the tie beam is tending to pull the Queen posts downwards, any sagging in the tie beam would tend to tip the two triangles, formed by the Queen posts, the principal rafters and the outer posts of the tie beams, inwards towards one another at their apexes. Consequently, on the strength and fixing of the straining beam depends the security of the truss.

Parts of the Queen Post Truss.—The truss for a span of 36 feet consists of a tie beam 11 × 5 inches, two Queen posts reduced to 5 × $4\frac{1}{2}$ inches each, with single splayed shoulder at the foot, and a splayed shoulder reversed at the top. The Queen posts are kept apart at the top by the *Straining Beam* 7 × 5 inches, and at the bottom laid along the tie beam there is a *Straining Sill* 4 × 3 inches, the purpose of which is to resist the tendency of the struts to force the feet of the Queen posts inwards. The two side triangles are formed of the *Principal Rafters* 6 × 5 inches in conjunction with the Queen posts and tie-beam end portions. Two purlins are required in each slope of roof, one being fixed over the Queen post and the second halfway between that and the pole plate. To support this second purlin a $4\frac{1}{2}$ × $2\frac{1}{2}$-inch strut is run from the splayed foot of the Queen post to the underside of the principal rafter. The common rafters are notched over these purlins and run from the pole plate to the ridge.

It will be clear that the discontinuance of the principal rafters at the heads of the Queen posts is a weakness, and where greater strength is required, Queen Post trusses are used in which the principals are continued to the underside of the ridge, the truss then becoming a combination of a Queen post and a King post truss, which forms the strongest type of timber roof.

The Joints used in the Queen Post Trust.—*Foot of Queen Post and the Beam.*—This consists, as in the King post truss, of a simple mortise and tenon to prevent side slipping, the tensile strain being counteracted by a wrought-iron strap secured to the Queen post by gib and cotters as before.

Foot of Queen Post and Strut.—The foot is broadened out with a splayed shoulder, on which is cut a mortise, which is continued up the vertical side of the Queen post a sufficient distance to take the tenon on the upper splayed face of the V-cut end of the strut.

Straining Sill and Queen Posts.—This is laid in with a butt joint, being most suitable for the resistance of the compression to which it is subjected.

Head of Queen Post and Principal Rafter.—The head of the Queen post is considerably cut into to receive, not only the principal rafter, but also the straining beam and the cleat under it.

The joint between the Queen post and the Principal rafter is the same as that employed with the Kingpost, the head being broadened out with a splayed shoulder.

Queen Post and Straining Beam.—The straining beam is tenoned into

the Queen post and housed with a bevelled shoulder, which affords a slight bearing for the weight of the straining beam. This, however, is additionally supported by a $10 \times 4 \times 3\frac{1}{2}$-inch cleat fixed underneath its end and let into the Queen post with a bevelled housing and spiked thereto.

Metal Straps.—These three timbers are strapped together with a three-way wrought-iron strap, each leg of which is secured by two $\frac{5}{8}$-inch bolts.

Purlin over Queen Post.—The head of the Queen post is carried up beyond the straining beam, and splay cut to provide the requisite angle of face to rest the purlin placed at right angles to the line of the pitch of the roof. To hold the purlin in this position a wedge-shaped cleat $11 \times 4 \times 3\frac{1}{2}$ inches is chase mortised into the upper surface of the straining beam.

Purlin over Strut.—This timber is cogged over the principal rafter at right angles to the pitch. And the purlins are cogged on the upper faces for the rafters. Under this purlin a $11 \times 4 \times 3\frac{1}{2}$-inch cleat is fixed with a chased mortise and tenon to give additional support.

Strut to Principal and Strut to Queen Post Foot are similar joints to those used in the King post truss.

Rafters and Gutters.—The method of finishing the rafter feet and the fixing of the *Pole Plate* is the same as for a King post truss.

Wide Gutters behind Parapet.—Where it is required to form a wide gutter behind a parapet, say about 2 feet 6 inches in width, upright studs are framed against the brickwork or masonry of the parapet wall and halved to the rafter feet and spiked thereto at their bottom ends. At their top ends they are halved and spiked to cross bearers run back horizontal till they meet the side of the rafters to which they are nailed. Gutter boarding 6×1 inch is laid over these lengthwise along the gutter.

The Mansard Roof.—This is the name given to a roof the slope of which is formed in two pitches, the lower a very steep pitch and the upper a flat one. The origin of this formation was the desire to use the roof space to the fullest, but at the same time to avoid a very tall roof; though it is condemned by Tredgold as being ungraceful and "causing loss of room as compared with the roof of high pitch," and further on account of difficulty in freeing the gutters from snow. All of which objections seeming rather trivial if true, it is a form now much used in the erection of office and other public buildings.

The Mansard Roof consists of two trusses, the upper one supporting the low-pitched portion of the roof being a King post truss, and the lower one, though not exactly a Queen post truss, is more like that than anything else. The vertical supports representing the Queen posts are fixed very near to the end of the tie beam of the King post truss above, and diagonal braces are run from near the end of the main beam, which runs under the Queen posts. Inclined studding or rafters outside these struts are run from the end of the main beam to a plate attached to the King post truss tie.

The jointing and strapping used in the construction of this truss is the same as that for the trusses already described.

Combination Truss—Queen Post and Princesses.—For spans over 45 feet, it will be clear that some intermediate support to the beam, additional to that afforded by the Queen post, will be required. This is given by intermediate posts being introduced between the Queen posts and the end of the tie beam; and a truss having one such intermediate post—a Princess—properly strutted in the same way as the Queen post, is suitable to support a roof of a span between 45 and 60 feet. The straining beam with the longer span requires support at its centre, and this is given by a minor King post either suspended from the ridge or carried by the principal rafter continued to the ridge.

Spans above 60 *feet* being in modern work usually constructed of steel, their description does not concern the carpenter, except in so far as they are part timber and part steel, though this practice also is fast becoming superseded by steelwork. The steel in these instances is substituted for the members in tension, as in the King bolt roof and the Trussed rafter roof, in which the principal rafter is supported by timber struts which are again supported by tension rods to the principal rafter.

Wood and Iron Collar Truss.—This is a form of truss used in roofing such rooms as assembly rooms in schools. It consists of an ordinary wood collar-beam roof truss with the principal rafters extended downwards, their feet being supported by metal shoes through which rods fitted with screw ends and nuts are run to the centre of the collar, where it is screwed to a tie rod, thus uniting it through the collar to the tops of the principals, which are fitted into a metal socket fitted with screw, bolt, and nut for tightening up the tie rod.

ROOF FINISH

Barge Boards.—To give an additional finish to a gable, boards wrought, and often carved, are fixed to the ends of the ridge, purlin, and wall plate, which are continued through the gable wall for that purpose. The purlin and wall plate are jointed to the barge board by being housed therein and the ridge is jointed by a double tenon let into a mortise cut in either the barge boards or a drop pendent, or gable post fixed over their junction.

Snow Boards are constructed of timber, and consist of a duckboard grating mounted on arched bearers cut out of 5×2 inches to raise them above the gutter and so keep the snow from causing a blockage.

Snow Guards, though not so necessary in the southern as in the northern districts, are useful on roofs having very long slopes. They are fixed above the eaves gutter to prevent the snow from falling in masses during thaws. They consist of a rail of four or five battens which should be teak, run horizontally parallel and just above the gutter, and are supported by galvanised-iron brackets let in under the bed tile or slate, and screwed to the upper surface of the rafter end.

SPAN OF JOISTS AND RAFTERS

	Size.	CLASS A TIMBERS SPAN				CLASS B TIMBERS SPAN			
		16-in. centres.	18-in. centres.	21-in. centres.	24-in. centres.	16-in. centres.	18-in. centres.	21 in. centres.	24-in. centres.
Floor Joists (Total load not exceeding 36 lb. per sq. foot).	3" × 1½"	3' 5"	3' 1"	2' 8"	2' 5"	2' 10"	2' 6"	2' 2"	1' 11"
	3" × 2"	4' 8"	4' 2"	3' 7"	3' 2"	3' 9"	3' 5"	2' 11"	2' 7"
	4" × 1½"	6' 0"	5' 5"	4' 8"	4' 2"	4' 11"	4' 5"	3' 10"	3' 5"
	4" × 2"	7' 11"	7' 1"	6' 3"	5' 6"	6' 6"	5' 10"	5' 1"	4' 6"
	5" × 1½"	8' 8"	8' 2"	7' 2"	6' 4"	7' 5"	6' 8"	5' 11"	5' 2"
	5" × 2"	9' 10"	9' 5"	8' 10"	8' 4"	8' 11"	8' 5"	7' 8"	6' 11"
	6" × 1½"	10' 5"	9' 10"	9' 1"	8' 7"	9' 3"	8' 9"	8' 2"	7' 4"
	6" × 2"	11' 10"	11' 4"	10' 7"	9' 11"	10' 9"	10' 2"	9' 6"	8' 11"
	6" × 2½"	12' 8"	12' 2"	11' 6"	10' 11"	11' 7"	11' 1"	10' 5"	9' 10"
	7" × 1½"	12' 3"	11' 7"	10' 9"	10' 1"	10' 11"	10' 3"	9' 7"	8' 11"
	7" × 2"	13' 11"	13' 3"	12' 5"	11' 8"	12' 7"	11' 11"	11' 1"	10' 5"
	7" × 2½"	14' 11"	14' 5"	13' 7"	12' 10"	13' 7"	13' 0"	12' 3"	11' 6"
	8" × 1½"	14' 1"	13' 4"	12' 4"	11' 7"	12' 6"	11' 10"	10' 11"	10' 3"
	8" × 2"	15' 11"	15' 3"	14' 4"	13' 5"	14' 5"	13' 9"	12' 10"	12' 0"
	8" × 2½"	17' 1"	16' 6"	15' 7"	14' 9"	15' 7"	14' 11"	14' 1"	13' 4"
	9" × 1½"	15' 8"	14' 10"	13' 9"	12' 11"	14' 0"	13' 3"	12' 3"	11' 6"
	9" × 2"	17' 10"	17' 0"	16' 0"	15' 0"	16' 1"	15' 4"	14' 4"	13' 5"
	9" × 2½"	19' 2"	18' 5"	17' 6"	16' 6"	17' 5"	16' 9"	15' 8"	14' 10"
Ceiling Joists Total load = 20 lb. per sq. foot)	3" × 1½"	6' 4"	6' 0"	5' 8"	5' 5"	5' 8"	5' 5"	5' 2"	4' 11"
	3" × 2"	6' 11"	6' 8"	6' 3"	6' 0"	6' 4"	6' 0"	5' 9"	5' 6"
	4" × 1½"	8' 6"	8' 2"	7' 10"	7' 5"	7' 9"	7' 6"	7' 1"	6' 8"
	4" × 2"	9' 6"	9' 1"	8' 6"	8' 3"	8' 6"	8' 2"	7' 10"	7' 6"
Rafters for type A roofs	3" × 1½"	6' 3"	6' 0"	5' 9"	5' 6"	5' 8"	5' 6"	5' 2"	5' 0"
	3" × 2"	7' 0"	6' 8"	6' 4"	6' 1"	6' 4"	6' 1"	5' 9"	5' 6"
	4" × 1½"	8' 6"	8' 2"	7' 9"	7' 5"	7' 9"	7' 5"	7' 1"	6' 9"
	4" × 2"	9' 5"	9' 0"	8' 7"	8' 3"	8' 7"	8' 3"	7' 10"	7' 6"
Rafters for type B roofs [See para. 22(*d*)]	3" × 1½"	6' 5"	6' 2"	5' 10"	5' 7"	5' 10"	5' 7"	5' 3"	5' 1"
	3" × 2"	7' 1"	6' 10"	6' 6"	6' 3"	6' 5"	6' 2"	5' 11"	5' 8"
	4" × 1½"	8' 8"	8' 5"	7' 11"	7' 7"	7' 11"	7' 7"	7' 3"	6' 11"
	4" × 2"	9' 8"	9' 3"	8' 10"	8' 5"	8' 9"	8' 5"	8' 0"	7' 8"
Joists for flat roofs. Total load not exceeding 35 lb. per sq. foot)	3" × 1½"	5' 1"	4' 9"	4' 5"	4' 2"	4' 6"	4' 3"	3' 11"	3' 8"
	3" × 2"	5' 9"	5' 6"	5' 2"	4' 10"	5' 3"	5' 0"	4' 7"	4' 4"
	4" × 1½"	6' 11"	6' 6"	6' 0"	5' 8"	6' 2"	5' 10"	5' 5"	5' 0"
	4" × 2"	7' 9"	7' 6"	7' 0"	6' 7"	7' 1"	6' 9"	6' 3"	5' 10"
	5" × 1½"	8' 8"	8' 2"	7' 7"	7' 1"	7' 9"	7' 4"	6' 9"	6' 4"
	5" × 2"	9' 10"	9' 6"	9' 0"	8' 4"	9' 0"	8' 7"	8' 0"	7' 5"
	6" × 1½"	10' 6"	10' 0"	9' 2"	8' 7"	9' 5"	8' 10"	8' 2"	7' 8"
	6" × 2"	12' 0"	11' 5"	10' 9"	10' 0"	10' 10"	10' 5"	9' 7"	9' 0"
	6" × 2½"	12' 9"	12' 3"	11' 8"	11' 1"	11' 7"	11' 2"	10' 7"	10' 0"
	7" × 1½"	12' 4"	11' 7"	10' 9"	10' 1"	11' 0"	10' 5"	9' 7"	9' 0"
	7" × 2"	13' 11"	13' 5"	12' 7"	11' 9"	12' 8"	12' 2"	11' 3"	10' 6"
	7" × 2½"	15' 0"	14' 4"	13' 8"	13' 0"	13' 7"	13' 1"	12' 5"	11' 8"
	8" × 1½"	14' 1"	13' 4"	12' 4"	11' 6"	12' 7"	12' 0"	11' 0"	10' 3"
	8" × 2"	16' 0"	15' 4"	14' 5"	13' 6"	14' 7"	14' 0"	13' 0"	12' 0"
	8" × 2½"	17' 2"	16' 6"	15' 8"	15' 0"	15' 7"	15' 0"	14' 3"	13' 4"
	9" × 1½"	15' 10"	15' 0"	13' 10"	13' 0"	14' 2"	13' 4"	12' 4"	11' 6"
	9" × 2"	18' 0"	17' 3"	16' 2"	15' 0"	16' 3"	15' 6"	14' 5"	13' 6"
	9" × 2½"	19' 3"	18' 6"	17' 6"	16' 0"	17' 6"	16' 10"	16' 0"	15' 0"

NOTE.—In this table " TYPE A ROOFS " means roofs of a pitch of not less than 40°, covered with plain tiles or natural slates of 7 inches or less width, the dead load not exceeding 17 lb. per sq. foot measured on the slope.

" TYPE B ROOFS " means roofs, of a pitch of not less than 35°, covered with interlocking tiles, asbestos-cement slates or natural slates of 8 inches width or wider, the dead load not exceeding 12 lb. per sq. foot of roof area measured on the slope.

SPAN OF PURLINS TO ROOFS OF TYPES A AND B

Type of roof.	Size of purlin.	CLASS A TIMBERS — Centres of purlins. 6′ 0″	7′ 0″	8′ 0″	9′ 0″	10′ 0″	CLASS B TIMBERS — Centres of purlins. 6′ 0″	7′ 0″	8′ 0″	9′ 0″	10′ 0″
Type A	4″ × 2″	4′ 5″	4′ 2″	4′ 0″	3′ 11″	3′ 8″	4′ 0″	3′ 9″	3′ 7″	3′ 6″	3′ 4″
	5″ × 2″	5′ 6″	5′ 3″	5′ 1″	4′ 10″	4′ 8″	5′ 0″	4′ 9″	4′ 7″	4′ 5″	4′ 3″
	6″ × 2″	6′ 8″	6′ 4″	6′ 1″	5′ 10″	5′ 8″	6′ 1″	5′ 9″	5′ 6″	5′ 4″	5′ 2″
	7″ × 2″	7′ 10″	7′ 6″	7′ 1″	6′ 10″	6′ 7″	7′ 2″	6′ 10″	6′ 6″	6′ 3″	6′ 0″
	8″ × 2″	9′ 0″	8′ 7″	8′ 2″	7′ 10″	7′ 7″	8′ 3″	7′ 10″	7′ 5″	7′ 2″	6′ 11″
	8″ × 3″	10′ 4″	9′ 9″	9′ 4″	9′ 0″	8′ 8″	9′ 5″	8′ 11″	8′ 6″	8′ 2″	7′ 11″
	9″ × 2″	10′ 2″	9′ 8″	9′ 3″	8′ 11″	8′ 7″	9′ 3″	8′ 9″	8′ 5″	8′ 1″	7′ 10″
	9″ × 3″	11′ 8″	11′ 1″	10′ 7″	10′ 2″	9′ 10″	10′ 7″	10′ 1″	9′ 7″	9′ 3″	8′ 11″
Type B	4″ × 2″	4′ 8″	4′ 5″	4′ 3″	4′ 2″	3′ 11″	4′ 3″	4′ 0″	3′ 10″	3′ 9″	3′ 7″
	5″ × 2″	5′ 11″	5′ 7″	5′ 5″	5′ 2″	5′ 0″	5′ 4″	5′ 1″	4′ 10″	4′ 8″	4′ 6″
	6″ × 2″	7′ 1″	6′ 9″	6′ 6″	6′ 3″	6′ 0″	6′ 5″	6′ 1″	5′ 10″	5′ 7″	5′ 5″
	7″ × 2″	8′ 4″	8′ 0″	7′ 7″	7′ 4″	7′ 1″	7′ 7″	7′ 2″	6′ 10″	6′ 7″	6′ 4″
	8″ × 2″	9′ 7″	9′ 1″	8′ 8″	8′ 5″	8′ 1″	8′ 8″	8′ 3″	7′ 10″	7′ 7″	7′ 4″
	8″ × 3″	11′ 0″	10′ 5″	10′ 0″	9′ 7″	9′ 3″	9′ 11″	9′ 5″	9′ 0″	8′ 8″	8′ 4″
	9″ × 2″	10′ 10″	10′ 3″	9′ 10″	9′ 5″	9′ 1″	9′ 9″	9′ 4″	8′ 11″	8′ 7″	8′ 3″
	9″ × 3″	12′ 5″	11′ 9″	11′ 3″	10′ 9″	10′ 5″	11′ 2″	10′ 8″	10′ 2″	9′ 9″	9′ 5″

NOTE.—In this table—(i) " Centres of purlins" means centre to centre measured on the slope or, for a single purlin, half the distance, measured on the slope, from the ridge to the eaves.

(ii) " Type A roofs " means roofs of a pitch of not less than 40° covered with plain tiles or natural slates of 7 inches or less width, the dead load not exceeding 17 lb. per sq. foot of roof area measured on the slope.

(iii) " Type B roofs " means roofs of a pitch of not less than 35°, covered with interlocking tiles, asbestos-cement slates or natural slates of 8 inches width or wider, the dead load not exceeding 12 lb. per sq. foot of roof area measured on the slope.

SPAN OF PURLINS FOR ROOFS COVERED WITH CORRUGATED ASBESTOS-CEMENT OR STEEL SHEETING

Size.	CLASS A TIMBERS — Centres of purlins. 3′ 0″	3′ 6″	4′ 0″	4′ 6″	5′ 0″	CLASS B TIMBERS — Centres of purlins. 3′ 0″	3′ 6″	4′ 0″	4′ 6″	5′ 0″
4″ × 2″	6′ 5″	6′ 1″	5′ 10″	5′ 7″	5′ 5″	5′ 10″	5′ 6″	5′ 3″	5′ 1″	4′ 11″
5″ × 2″	8′ 1″	7′ 8″	7′ 4″	7′ 1″	6′ 10″	7′ 4″	7′ 0″	6′ 8″	6′ 5″	6′ 3″
6″ × 2″	9′ 8″	9′ 3″	8′ 10″	8′ 7″	8′ 3″	8′ 10″	8′ 5″	8′ 1″	7′ 9″	7′ 6″
7″ × 2″	11′ 5″	10′ 10″	10′ 5″	10′ 0″	9′ 8″	10′ 5″	9′ 11″	9′ 5″	9′ 1″	8′ 9″
8″ × 2″	13′ 1″	12′ 5″	11′ 11″	11′ 6″	11′ 0″	11′ 11″	11′ 4″	10′ 10″	10′ 5″	10′ 1″
8″ × 3″	15′ 0″	14′ 3″	13′ 8″	13′ 1″	12′ 8″	13′ 7″	13′ 0″	12′ 5″	11′ 11″	11′ 6″
9″ × 2″	14′ 9″	14′ 1″	13′ 5″	12′ 8″	12′ 5″	13′ 5″	12′ 10″	12′ 3″	11′ 9″	11′ 4″
9″ × 3″	16′ 11″	16′ 1″	15′ 5″	14′ 10″	14′ 4″	15′ 5″	14′ 8″	14′ 0″	13′ 5″	13′ 0″

NOTE.—In this table, " centres of purlins " means centre to centre measured on the slope, or, for a single purlin, half the distance, measured on the slope, from ridge to eaves.

FLOOR BOARDS FOR TWO-STOREY DWELLING HOUSES IN ONE OCCUPATION

Centres of supports.	Thickness of floorboards. Tongued and grooved.	Plain-edged (not less than 6 in. wide)
16″	$\frac{3}{4}''$	$\frac{7}{8}''$
18″	$\frac{3}{4}''$	1″
21″	$\frac{7}{8}''$	$1\frac{1}{8}''$
24″	1″	$1\frac{1}{4}''$

CHAPTER 5

USE OF THE STEEL SQUARE

STRICTLY speaking, there is no such thing as *the* steel square, for there are many kinds, differing in size, construction, and markings. All, however, have a long blade and a shorter, usually narrower, tongue, placed, as in other squares, at right angles to each other. Both blade and tongue are marked back and front on inner and outer edges with scales designed to facilitate all calculations needed by carpenters, bricklayers, and other building craftsmen. Further, both blades and tongue, back and front, are scored with a variety of scales and tables. It is principally in these additional tables that steel squares differ from one another.

Steel squares, while capable of very wide application, are probably more often used in roof construction, and it is in this connection that their advantages, and the way of using them, are easiest to understand. The usual proceeding in roof work is to set down on paper a plan of the roof, showing length, breadth, and rise, and by extension lines ascertaining the length of rafters and the angles for foot and plumb cuts for top and base of timbers. By using a steel square such paper work is rendered unnecessary, as the scales on edges will give the needed run of hip or rafter in relation to span and rise, and at the same time give the diagonals for the several cuts. Such tools, therefore, are great savers of time and effort, though they call for careful study.

TYPES OF STEEL SQUARES

As a rule a steel square has a blade 24 inches long by 2 inches wide, and a tongue 18 inches long by $1\frac{1}{2}$ inches wide. Others have blades 12 inches and 18 inches long by $1\frac{1}{2}$ inches wide, and tongues 16 inches, 12 inches, and 8 inches long by $1\frac{3}{4}$ inches to 1 inch wide. The standard type first mentioned, however, is by far the most satisfactory for general purposes. The last kind are stamped out in one piece from solid metal, not in two pieces and then welded at the angle. But "take-down" steel squares are also made, blade and tongue being separate, constructed to fix and unfix at the angle. While these are convenient for carrying about, the one-piece is perhaps more reliable and certainly gives far less trouble.

SCALES AND TABLES

As already mentioned, inner and outer edges on both sides of blade and tongue are marked with scales; these give inches and fractions of

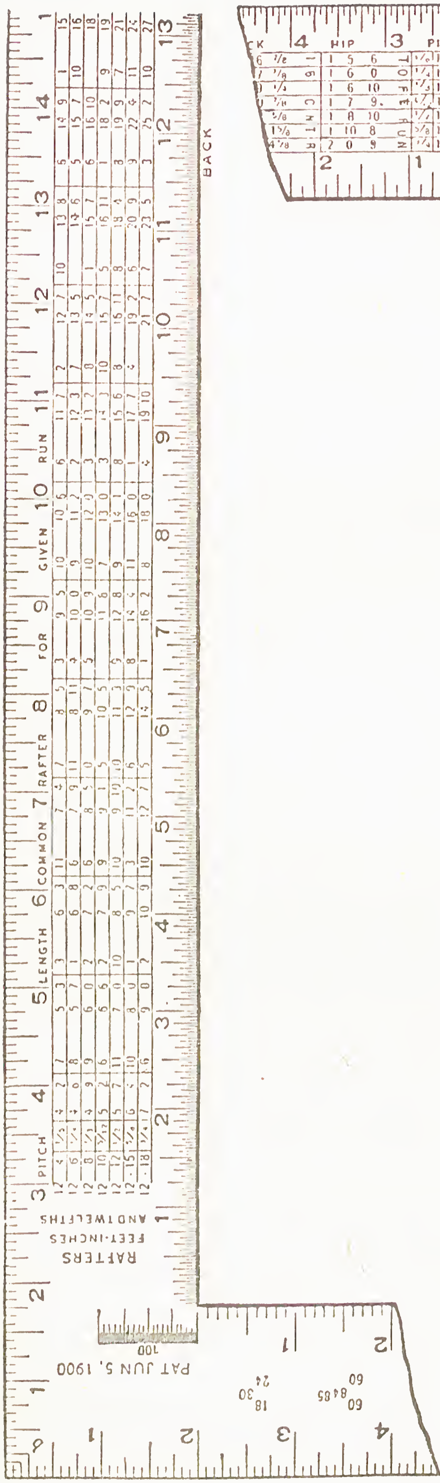


Fig. 70.

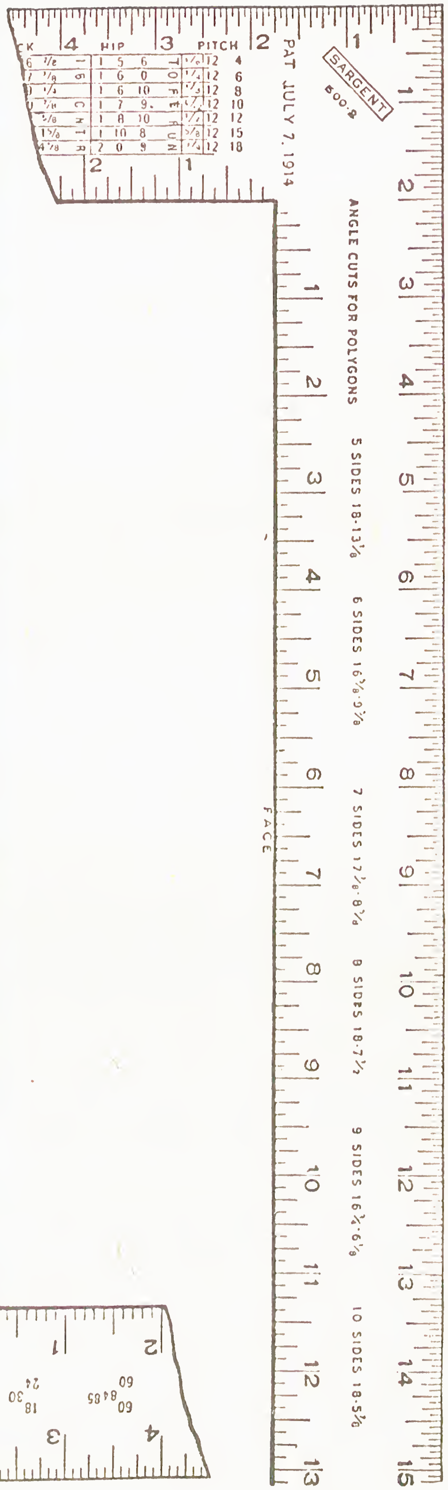


Fig. 71.

Fig. 72.

inches. On the front side the outer inch scale is divided into halves, quarters, and eighths, and the inner into twelfths. On the back side the inner edge is divided into eighths and the outer edge into sixteenths. The inner edge of the front side in conjunction with a table on the blade serves as a board measure. On a standard type of steel square, such as the Sargent, we find on the front side of the tongue a diagonal scale marking off hundredths of inches ; as well as a brace scale, giving the lengths of a brace of a stated rise and run (*i.e.* the length of the hypotenuse of a right-angled triangle with equal sides). On the back of the tongue is found an octagonal scale marked in tenths. There are also scales for rafters (common, jack, and hip), with pitch, angle cuts for polygons, and so on. The common rafter table includes gradations on the back of both blade and tongue, accurately marked in twelfths, to be taken in inches or feet as the case may require. These gradations give the "runs" or lengths, which are thus ascertainable to a fraction ; and at the top of the table is found the scale for pitch or rise, being placed close together for easy calculation. On some squares other tables are marked, while in others certain modifications are found, but the above record enumerates the essential features of the tool, modifications readily being understood by anybody having some knowledge of mathematics and practice in geometry. Although there is a natural desire to crowd as much information as possible on a square, over-complication should be avoided quite as much as the too drastic simplification usually found on cut-down patterns.

HOW A STEEL SQUARE IS USED

As blade and tongue are gauged to their respective widths of 2 inches and 1½ inches, the square can be used for setting out on the timber itself, the tool being reversed when needed in the form of a double square. The rule markings on the inner edges can be used to measure off the spacing and set out both positions at a single setting. In laying out stud partitions for wall board or metal lathing the positions of the intermediate studs are found by marking the end timber with two lines (2 inches or 1½ inches apart), place the square against this, mark on both sides of the blade or tongue, and so proceed for the whole run. Thus, if a standard 4-foot sheet is to have three intermediate studs, spaced equally apart, the 12-inch mark on inner edge will give the spacing, and the pencil mark on edge side of the square the width of the stud. Joists to be mortised for square trimming are set out in the same way. Here bevel cuts will be needed, which are obtained by the requisite pair of duplicate figures on blade and tongue, which will give shoulder cuts and mortise bevels.

To ascertain the length of rafters, the span and pitch being known, follow the line of pitch to the length of run or span, and under that number will be found the result in feet and fractions of feet. As these figures

give lengths from centre of ridge board to edge of wall plate, it is necessary to deduct half the thickness of the ridge board and then add for any projection beyond the wall plate or eaves. If the run is of a broken number, say 12 feet 5 inches, then it will be necessary to make two calculations, one for feet and the other for inches, adding the results together. The points for the top and bottom cuts (the plumb and foot bevels) are found by placing the square on the rafter so that one arm represents the run (span) and the other the rise (pitch). For jack rafters there is a special table on the tool, giving the lengths of the shortest jack (deducting, as before, for half the thickness of the hip, or valley, rafter and adding for any projection beyond the wall plate), the difference for each succeeding rafter for given centres as found on the table marked on the tool also being indicated. For plumb and heel cuts, the figures on the blade and tongue are taken respectively. The same methods are followed for the hip rafters, and the cuts for sheathing (boarding) found by reversing the figures.

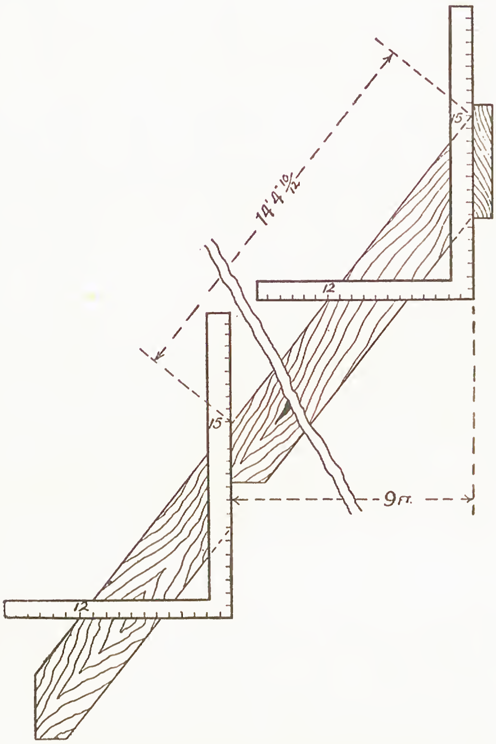


Fig. 73.—Use of steel square on rafters.

ROOFING TABLES

The following table for roofing cuts will be found useful :

Tongue.	*Blade.*	*Cut.*
Rafter run and	Rafter rise give	Rafter plumb and foot cuts.
	(Distance between these points gives rafter length.)	
Rafter run and	Rafter length give	Jack splay, top cut of roof-boards and top of purlin mitre.
Rafter run and	Rafter run give	Hip and valley run.
Hip run and	Rafter rise give	Hip and valley plumb with foot cuts.
	(Distance between these points gives hip or valley lengths.)	
Rafter rise and	Hip length give	Hip backing.
Rafter rise and	Rafter length give	Side purlin mitre.
Hip run and	Hip length give	Hip splay.

Rafter run and rafter rise will give rafter plumb and foot cuts, whether we take the whole run of the rafter with its whole rise, as was formerly done, or take its run for 1 foot and the rise for 1 foot as is customary now. And so with all the other cuts. Whether the value for the whole span or the value for 1 foot of span is selected, the cuts will be identical.

More explicit than the table on p. 118 are the following two tables, compiled and carefully checked by Mr. H. R. Vincent, which will facilitate the application of the steel square to roof work. These are supplementary to the detailed table. It should be understood that they serve the purpose of an index, showing on what part of the steel square the exact figures required are to be found.

Table No. 1 provides a simple method how to obtain the seat and plumb cuts for common rafters, hips, jack rafters, and purlins, with the necessary particulars as to run, length, and rise. It is in fact just a matter of following down the first column and across in order to secure a guide to the correct solution. Thus, the column rafter seat cut is shown to be found on the body and the plumb cut on the tongue, while the run is formed on the body and the rise on the tongue.

Turning to Table No. 2, under "Lengths Wanted," we find rafter lengths, and following across we see that the run is to be found on the body and the rise on the tongue. Measuring across these two points the desired length is ascertained.

The cuts for jacks are obtained in the same way as for common rafters, while the side cuts are, as shown in Table 1 (column 1, line 7), found on the tongue.

Valleys may be regarded as another, reversed, form of the hip, so that the columns in Table 1 for hips will serve valleys, whether oblique or uneven pitched.

Boarding bearing exactly the same position as the purlins, their top and foot cuts will be identical with the top and bottom cuts for purlins.

TABLE NO. 1

How to Ascertain Cuts by Use of Steel Square

Cut required.	Where cut is found.	Body use.	Tongue use.
Common Rafter Seat	Body	Rafter run	Rise
Common Rafter Plumb	Tongue	Rafter run	Rise
Hip: Plumb	Tongue	Hip run	Rise
Hip: Seat	Body	Hip run	Rise
Hip: Side	Tongue	Hip run	Hip length
Hip: Backing	Tongue	Hip length	Rise
Side: Jacks	Tongue	Rafter run	Rafter length
Top: Purlin	Body	Rafter run	Rafter length
Side: Purlin	Tongue	Rafter length	Rise

TABLE NO. 2

How to Ascertain Lengths by Use of Steel Square

Lengths wanted.	Body use.	Tongue use.	Length.
Rafter length	Rafter run	Rise	Third side
Hip run	Rafter run	Rafter run	Third side
Hip length	Hip run	Rise	Third side

Rafter run = Half span.

EVEN RISE ROOFING TABLE, GIVING LENGTH

Inches of rise in one foot.	Span of Rafter. 1	2	3	4	5	6	7	8	9	10
1	1- 0- 1	2- 0- 1	3- 0- 2	4- 0- 2	5- 0- 3	6- 0- 3	7- 0- 4	8- 0- 4	9- 0- 5	10- 0-
2	1- 0- 2	2- 0- 4	3- 0- 6	4- 0- 8	5- 0-10	6- 1- 0	7- 1- 2	8- 1- 4	9- 1- 6	10- 1-
3	1- 0- 4	2- 0- 9	3- 1- 1	4- 1- 6	5- 1-10	6- 2- 3	7- 2- 7	8- 2-11	9- 3- 4	10- 3-
4	1- 0- 8	2- 1- 4	3- 1-11	4- 2- 7	5- 3- 3	6- 3-11	7- 4- 7	8- 5- 2	9- 5-10	10- 6-
5	1- 1- 0	2- 2- 0	3- 3- 0	4- 4- 0	5- 5- 0	6- 6- 0	7- 7- 0	8- 8- 0	9- 9- 0	10-10-
6	1- 1- 5	2- 2-10	3- 4- 3	4- 5 8	5- 7- 1	6- 8- 6	7- 9-11	8-11- 4	10- 0- 9	11- 2-
7	1- 1-11	2- 3- 9	3- 5- 8	4- 7- 7	5- 9- 6	6-11- 4	8- 1- 3	9- 3- 2	10- 5- 0	11- 6-
8	1- 2- 5	2- 4-10	3- 7- 3	4- 9- 8	6- 0- 1	7- 2- 6	8- 4-11	9- 7- 5	10- 9-10	12- 0-
9	1- 3- 0	2- 6- 0	3- 9- 0	5- 0- 0	6- 3- 0	7- 6- 6	8- 9- 0	10- 0- 0	11- 3- 0	12- 6-
10	1- 3- 8	2- 7- 3	3-10-11	5- 2- 6	6- 6- 2	7- 9- 9	9- 2- 5	10- 7- 0	11- 9- 8	13- 0-
11	1- 4- 3	2- 8- 7	4- 0-10	5- 5- 1	6- 9- 5	8- 1- 8	9- 5-11	10-10- 3	12- 2- 6	13- 6-
12	1- 5- 0	2- 9-11	4- 2-11	5- 7-11	7- 0-11	8- 5-10	9-10-10	11- 3-10	12- 8- 9	14- 1-
13	1- 5- 8	2-11- 5	4- 5- 1	5-10- 9	7- 4- 6	8-10- 2	10- 3-10	11- 9- 6	13- 3- 3	14- 8-
14	1- 6- 5	3- 0-11	4- 7- 4	6- 1- 9	7- 8 2	9- 2- 8	10- 9- 1	12- 3- 6	13- 9-11	15- 4-
15	1- 7- 2	3- 2- 5	4- 9- 8	6- 4-10	8- 0- 1	9- 7- 3	11- 2 -6	12-11- 8	14- 4-10	16- 0-
16	1- 8- 0	3- 4- 0	5- 0- 0	6- 8- 0	8- 4- 0	10- 0- 0	11- 8- 0	13- 4- 0	15- 0- 0	16- 8-
17	1- 8 10	3- 5- 7	5- 2- 5	6-11- 3	8- 8- 0	10- 4-10	12- 1- 8	13-10- 6	15- 7- 3	17- 4-
18	1- 9- 8	3- 7- 3	5- 4-11	7- 2- 6	9- 0- 2	10- 9-10	12- 7- 5	14- 5- 1	16- 2- 8	18- 0-
19	1-10- 6	3- 8-11	5- 7- 5	7- 5-11	9- 4- 4	11- 2-10	13 1- 4	14-11- 9	16-10- 3	18- 8-
20	1-11- 4	3-10- 8	5-10- 0	7- 9- 4	9- 8- 8	11- 7-11	13- 7- 3	15- 6- 7	17- 5-11	19- 5-
21	2- 0- 2	4- 0- 5	6- 0- 7	8- 0- 9	10- 0-11	12- 1- 2	14- 1- 4	16- 1 6	18- 1- 8	20- 1-
22	2- 1- 1	4- 2- 1	6- 3- 2	8- 4- 3	10- 5- 4	12- 6- 4	14- 7- 5	16- 8- 6	18- 9- 7	20-10-
23	2- 1-11	4- 3-11	6- 5-10	8- 7- 9	10- 9- 9	12-11- 8	15- 1- 8	17- 3- 7	19- 5- 6	21- 7-
24	2- 2-10	4- 5- 8	6- 8- 6	8-11- 4	11- 2- 2	13- 5- 0	15- 7-10	17-10- 8	20- 1- 6	22- 4-
25	2- 3- 9	4- 7- 6	6-11- 3	9- 2-11	11- 6- 8	13-10- 5	16- 2- 2	18- 5-11	20- 9- 8	23- 1-

EXAMPLE SHOWING U

Read the rafter span found at head of this table in feet, in inches, or
rise to the foot of span are to be read in feet, in inches, or in twelfths accor
6 *feet* to have a rafter length of 10 *feet*, for a span of 6 *inches* it has a raft
10 *twelfths*. Then a rafter of 16″ pitch, that is to span 6′ 6½″, will have

EVEN RISE ROOFING TABLE, GIVING LENGTH

Inches of rise in one foot.	Span of Rafter. 1	2	3	4	5	6	7	8	9	10
1	1- 5- 0	2-10- 0	4- 3- 0	5- 8- 0	7- 1- 0	8- 6- 0	9-11- 0	11- 4- 0	12- 9- 0	14- 2-
2	1- 5- 1	2-10- 2	4- 3- 3	5- 8- 4	7- 1- 5	8- 6- 6	9-11- 7	11- 4- 8	12- 9- 9	14- 2-
3	1- 5- 3	2-10- 6	4- 3- 9	5- 8-11	7- 2- 2	8- 7- 5	10- 0- 8	11- 5-11	12-11- 2	14- 4-
4	1- 5- 5	2-10-11	4- 4- 4	5- 9- 9	7- 3- 2	8- 8- 7	10- 2- 1	11- 7- 6	13- 0-11	14- 6-
5	1 5- 8	2-11 5	4- 5- 1	5-10- 9	7- 4- 6	8-10- 2	10- 3-10	11- 9- 6	13- 3- 3	14- 8-
6	1 6- 0	3- 0- 0	4- 6- 0	6- 0- 0	7- 6- 0	9- 0- 0	10- 6- 0	12- 0- 0	13- 6- 0	15- 0-
7	1- 6- 4	3- 0- 9	4- 7- 1	6- 1- 5	7- 7- 9	9- 2- 2	10- 8- 6	12- 2-10	13- 9- 3	15- 3-
8	1- 6- 9	3- 1- 6	4- 8- 3	6- 3- 1	7- 9-10	9- 4- 7	10-11- 4	12- 6- 1	14- 0-10	15- 7-
9	1- 7- 2	3- 2- 5	4- 9- 8	6- 4-10	8- 0- 1	9- 7- 3	11- 2- 6	12- 9- 8	14- 4-11	16- 0-
10	1- 7- 8	3- 3- 5	4-11- 1	6- 6-10	8- 2- 6	9-10- 2	11- 5-11	13- 1- 7	14- 9- 3	16- 5-
11	1- 8- 3	3- 4- 5	5- 0- 8	6- 8-11	8- 5- 2	10- 1- 4	11- 9- 7	13- 5-10	15- 2- 0	16-10-
12	1- 8- 9	3- 5- 7	5- 2- 4	6-11- 2	8- 7-11	10- 4- 8	12- 1- 6	13-10- 3	15- 7- 1	17- 3-
13	1- 9- 5	3- 6- 9	5- 4- 2	7- 1- 6	8-10-11	10- 8- 3	12- 5- 8	14- 3- 0	16- 0- 5	17- 7-
14	1-10- 0	3- 8- 0	5- 6- 0	7- 4- 0	9- 2- 0	11- 0- 0	12-10- 0	14- 8- 0	16- 6- 0	18- 4-
15	1-10- 8	3- 9- 4	5- 7-11	7- 6- 7	9- 5- 3	11- 3-11	13- 2- 7	15- 1- 2	16-11-10	18-10-
16	1-11- 4	3-10- 8	5-10- 0	7- 9- 4	9- 8- 7	11- 7-11	13- 7- 3	15- 6- 7	17- 5-11	19- 5-
17	2- 0- 0	4- 0- 1	6- 0- 1	8- 0- 1	10- 0- 2	12- 0- 2	14- 0- 2	16- 0- 3	18- 0- 3	20- 0-
18	2- 0- 9	4- 1- 6	6- 2- 3	8- 3- 0	10- 3- 8	12- 4- 5	14- 5- 2	16- 5-11	18- 6- 8	20- 7-
19	2- 1- 6	4- 2-11	6- 5- 4	8- 5-11	10- 7- 5	12- 8-10	14-10- 4	16-11-10	19- 1- 4	21- 2-
20	2- 2- 3	4- 4- 6	6- 6- 8	8- 8-11	10-11- 2	13- 1- 5	15- 3- 7	17- 5-10	19- 8- 1	21-10-
21	2- 3- 0	4- 6- 0	6- 9- 0	9- 0- 0	11- 3- 0	13- 6- 0	15- 9- 0	18- 0- 0	20- 3- 0	22- 6-
22	2- 3- 9	4- 7- 7	6-11- 4	9- 3- 2	11- 6-11	13-10- 9	16- 2- 6	18- 6- 5	20-10- 1	23- 1-
23	2- 4- 7	4- 9- 2	7- 1- 9	9- 6- 4	11-10-11	14- 3- 6	16- 8- 1	19- 0- 8	21- 5- 3	23- 9-
24	2- 5- 5	4-10- 9	7- 4- 2	9- 9- 7	12- 3- 0	14- 8- 4	17- 1- 9	19- 7- 2	22- 0- 7	24- 5-
25	2- 6- 3	5- 0- 5	7- 6- 8	10- 0-10	12- 7- 1	15- 1- 4	17- 7- 6	20- 1- 9	22- 7-11	25- 2-

EXAMPLE SHOWING U

At head of this table read the same span that you have used for yo
hip and valley lengths given for every inch of rise in the table are a
to rise 14″ in one foot, for a rafter span of 6 *feet*, we have a hip and vall
for a span of 6 *twelfths* (or ½″) we have a hip length of 11 *twelfths*. Then
11-11-11, or, in full, 11 feet 11 inches and 11 twelfths.

OF RAFTERS FOR EVERY INCH OF RISE

Span of Rafter.										
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Inches of rise in one foot.**
11- 0- 6	12- 0- 6	13- 0- 7	14- 0- 7	15- 0- 8	16- 0- 8	17- 0- 9	18- 0- 9	19- 0-10	20- 0-10	1
11- 1-10	12- 2- 0	13- 2- 2	14- 2- 4	15- 2- 6	16- 2- 8	17- 2-10	18- 3- 0	19- 3- 2	20- 3- 4	2
11- 4- 1	12- 4- 5	13- 4-10	14- 5- 2	15- 5- 7	16- 5-11	17- 6- 3	18- 6- 8	19- 7- 0	20- 7- 5	3
11- 7- 2	12- 7-10	13- 8- 5	14- 9- 1	15- 9- 9	16-10- 5	17-11- 0	18-11- 8	20- 0- 4	21- 1- 0	4
11-11- 0	13- 0- 0	14- 1- 0	15- 2- 0	16- 3- 0	17- 4- 0	18- 5 0	19- 6- 0	20- 7- 0	21- 8- 0	5
12- 3- 7	13- 5- 1	14- 6- 5	15- 7-10	16- 9- 3	17-10- 8	19- 0- 1	20- 1- 6	21- 2-11	22- 4- 4	6
12- 8-10	13-10- 9	15- 0- 7	16- 2- 6	17- 4- 5	18- 6- 3	19- 8- 2	20-10- 1	21-11-11	23- 1-10	7
13- 2- 8	14 5- 1	15- 7- 6	16- 9-11	18- 0- 4	19- 2- 9	20- 5- 2	21- 7- 7	22-10- 0	24- 0- 5	8
13- 9- 0	15- 0- 0	16- 3- 0	17- 6- 0	18 9- 0	20- 0- 0	21- 3- 0	22- 6- 0	23- 9- 0	25- 0- 0	9
14- 3-11	15- 7- 6	16-11 2	18- 2- 9	19- 6- 5	20-10- 0	22- 1- 8	23- 5- 3	24- 8-11	26- 0- 6	10
14-11- 1	16- 3- 4	17- 7- 7	18-11-11	20- 4- 2	21- 8- 6	23- 0- 9	24- 5- 0	25- 9- 4	27- 1- 7	11
15- 6- 9	16-11- 8	18- 4- 8	19- 9- 8	21- 2- 7	22- 7- 7	24- 0- 7	25- 5- 7	26-10- 6	28- 3- 6	12
16- 2- 7	17- 8- 4	19- 2- 0	20- 7- 8	22- 1- 5	23- 7- 1	25- 0- 9	26- 6- 5	28- 0- 2	29- 5-10	13
16-10-10	18- 5- 3	19-11- 8	21- 6- 2	23- 0- 7	24- 7- 0	26- 1- 6	27- 7-11	29 2- 4	30- 8- 9	14
17- 7- 4	19- 2- 6	20- 9- 9	22- 4-11	24- 0- 2	25- 7- 4	27- 2- 7	28- 9- 9	30- 5- 0	32- 0- 2	15
18- 4- 0	20- 0- 0	21- 8- 0	23- 4- 0	25- 0- 0	26- 8- 0	28- 4- 0	30- 0- 0	31- 8- 0	33- 4- 0	16
19- 0-11	20- 9- 8	22- 6- 6	24- 3- 4	26- 0- 1	27- 8-11	29- 5- 8	31- 2- 6	32-11- 4	34- 8- 2	17
19-10- 0	21- 7- 7	23- 5- 3	25- 2-10	27- 0- 6	28-10- 2	30- 7- 9	32- 5- 5	34- 3- 0	36- 0- 8	18
20- 7- 2	22- 5- 8	24- 4- 2	26- 2- 7	28- 1- 1	29-11- 7	31-10- 0	33- 8- 6	35- 7- 0	37- 5- 5	19
21- 4- 7	23- 3-11	25- 3- 3	27- 2- 6	29- 1-10	31- 1- 2	33- 0- 6	34-11-10	36-11- 2	38-10- 6	20
22- 2- 1	24- 2- 3	26- 2- 5	28- 2- 7	30- 2-10	32- 3- 0	34- 3- 2	36- 3- 4	38- 3- 7	40- 3- 9	21
22-11- 8	25- 0- 9	27- 1- 9	29- 2-10	31- 3-11	33- 4-11	35- 6- 0	37- 7- 1	39- 8- 2	41- 9- 2	22
23- 9- 5	25-11- 4	28- 1- 3	30- 3- 2	32- 5- 2	34- 7- 1	36- 9- 0	38-11- 0	41- 0-11	43- 2-10	23
24- 7- 2	26-10- 0	29 -0-10	31- 3- 8	33- 6- 6	35- 9- 4	38- 0- 2	40- 3- 0	42- 5-10	44- 8- 8	24
25- 5- 2	27- 8-10	30- 0- 7	32- 4- 4	34- 8- 1	36-11-10	39- 3- 7	41- 7- 4	43-11- 0	46- 2- 9	25

OF THIS TABLE.

twelfths, as your span requires. Then rafter lengths given for every inch of ingly. Thus a rafter that is to rise 16″ in one foot is shown for a span of length of 10 *inches*, and for a span of 6 *twelfths* (or ½″) it has a rafter length of rafter length of 10–10–10, or, in full, 10 feet 10 inches and 10 twelfths.

OF HIPS AND VALLEYS FOR EVERY INCH OF RISE

Span of Rafter.										
11	**12.**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Inches of rise in one foot.**
15- 7- 0	17- 0- 0	18- 5- 0	19-10- 0	21- 3- 0	22- 8- 0	24- 1- 0	25- 6- 0	26-11- 0	28- 4- 0	1
15- 7-11	17- 1- 1	18- 6- 2	19-11- 3	21- 4- 4	22- 9- 5	24- 2- 6	25- 7- 7	27- 0- 8	28- 5- 9	2
15- 9- 7	17- 2-10	18- 8- 1	20- 1- 4	21- 6- 7	22-11-10	24- 5- 0	25-10- 3	27- 3- 6	28- 8- 9	3
15-11-10	17- 5- 3	18-10- 8	20- 4- 1	21- 9- 6	23- 2- 0	24- 8- 5	26- 1-10	27- 7- 3	29- 0- 9	4
16- 2- 7	17- 8- 4	19- 2- 0	20- 7- 8	22- 1- 5	23- 7- 1	25- 0- 9	26- 6- 5	28- 0- 2	29- 5-10	5
16- 6- 0	18- 0- 0	19- 6- 0	21- 0- 0	22- 6- 0	24- 0- 0	25- 6- 0	27- 0- 0	28- 6- 0	30- 0- 0	6
16- 9-11	18- 4- 4	19-10- 8	21- 5- 0	22-11- 4	24- 5- 9	26- 0- 1	27- 6- 5	29- 0-10	30- 7- 2	7
17- 2- 5	18- 9- 2	20- 3-11	21-10- [illegible]	23- 5- 5	25- 0- 2	26- 6-11	28- 1- 8	29- 8- 6	31- 3- 3	8
17- 7- 4	19- 2- 6	20- 9- 9	22- 4-11	24- 0- 2	25- 7- 4	27- 2- 7	28- 9- 9	30- 5- 0	32- 0- 2	9
18- 0- 8	19- 8- 5	21- 4- 1	22-11- 9	24- 7- 6	26- 3- 2	27-10-10	29- 6- 7	31- 2- 3	32- 9-11	10
18- 6- 6	20- 2- 8	21-10-11	23- 7- 2	25- 3- 4	26-11- 7	28- 7-10	30- 4- 0	32- 0- 3	33- 8- 6	11
19- 0- 8	20- 9- 5	22- 6- 2	24- 3- 0	25-11- 9	27- 8- 7	29- 5- 4	31- 2- 2	32-10-11	34- 7- 8	12
19- 7- 2	21- 4- 6	23- 1-11	24-11- 3	26- 8- 8	28- 6- 1	30- 3- 5	32- 0-10	33-10- 2	35- 7- 7	13
20- 2- 0	22- 0- 0	23-10- 0	25- 8- 0	27- 6- 0	29- 4- 0	31- 2- 0	33- 0- 0	34-10- 0	36- 8- 0	14
20- 9- 2	22- 7-10	24- 6- 5	26- 5- 1	28- 3- 9	30- 2- 5	32- 1- 1	33-11- 8	35-10- 4	37- 9- 0	15
21- 4- 7	23- 3-11	25- 3- 2	27- 2- 6	29- 1-10	31- 1- 2	33- 0- 6	34-11-10	36-11- 2	38-10- 6	16
22- 0- 4	24- 0- 4	26- 0- 4	28- 0- 5	30- 0- 5	32- 0- 5	34- 0- 6	36- 0- 6	38- 0- 6	40- 0- 7	17
22- 6- 2	24- 8-10	26- 9- 7	28-10- 4	30-11- 1	32-11-10	35- 0- 7	37- 1- 4	39- 2- 1	41- 2- 9	18
23- 4- 3	25- 5- 8	27- 7- 2	29- 8- 8	31-10- 2	33-11- 7	36- 1- 1	38- 2- 7	40- 4- 1	42- 5- 6	19
24- 0- 6	26- 2- 9	28- 5- 0	30- 7- 3	32- 9- 5	34-11- 8	37- 1-11	39- 4- 2	41- 6- 5	43- 8- 7	20
24- 9- 0	27- 0- 0	29- 3- 0	31- 6- 0	33- 9- 0	36- 0- 0	38- 3- 0	40- 6- 0	42- 9- 0	45- 0- 0	21
25- 5- 8	27- 9- 5	30- 1- 2	32- 5- 0	34- 8- 9	37- 0- 7	39- 4- 4	41- 8- 2	43-11-11	46- 3- 8	22
26- 2- 5	28- 7- 0	30-11- 7	33- 4- 2	35- 8- 9	38- 1- 4	40- 5-11	42- 10-6	45- 3- 1	47- 7- 8	23
26-11- 4	29- 4- 9	31-10- 2	34- 3- 6	36- 8-11	39- 2- 4	41- 7- 8	44- 1- 1	46- 6- 6	48-11-11	24
27- 8- 5	30- 2- 7	32- 8-10	35- 3- 0	37- 9- 3	40- 3- 6	42- 9- 8	45- 3-11	47-10- 1	50- 4- 4	25

OF THIS TABLE.

rafter pattern in feet, in inches, or in twelfths, as your span requires. Then to be read in feet, in inches, or in twelfths accordingly. Thus on a roof that is length of 11 *feet*, for a span of 6 *inches* we have a hip length of 11 *inches*, and the 14″ pitch, when the rafter spans 6′ 6½″, the hip or valley length will be

DEGREE ROOFING TABLE, GIVING LENGTHS

Pitch of roof in degrees.	Span of Rafter.									
	1	2	3	4	5	6	7	8	9	10
12	1- 0- 3	2- 0- 6	3- 0-10	4- 1- 1	5- 1- 4	6- 1- 7	7- 1-11	8- 2- 2	9- 2- 5	10- 2- 8
13	1- 0- 4	2- 0- 8	3- 0-11	4- 1- 3	5- 1- 7	6- 1-11	7- 2- 2	8- 2- 6	9- 2-10	10- 3- 2
14	1- 0- 4	2- 0- 9	3- 1- 1	4- 1- 6	5- 1-10	6- 2- 2	7- 2- 7	8- 2-11	9- 3- 4	10- 3- 8
15	1- 0- 5	2- 0-10	3- 1- 3	4- 1- 8	5- 2- 1	6- 2- 6	7- 3- 0	8- 3- 5	9- 3-10	10- 4- 3
16	1- 0- 6	2- 1- 0	3- 1- 5	4- 1-11	5- 2- 5	6- 2-11	7- 3- 5	8- 3-10	9- 4- 4	10- 4-10
17	1- 0- 7	2- 1- 1	3- 1- 8	4- 2- 2	5- 2- 9	6- 3- 3	7- 3-10	8- 4- 5	9- 4-11	10- 5- 6
18	1- 0- 7	2- 1- 3	3- 1-10	4- 2- 5	5- 3- 1	6- 3- 8	7- 4- 4	8- 4-11	9- 5- 7	10- 6- 2
19	1- 0- 8	2- 1- 5	3- 2- 1	4- 2- 9	5- 3- 5	6- 4- 2	7- 4-10	8- 5- 6	9- 6- 3	10- 6-11
20	1- 0- 9	2- 1- 7	3- 2- 4	4- 3- 1	5- 3-10	6- 4- 8	7- 5- 5	8- 6- 2	9- 6-11	10- 7- 8
21	1- 0-10	2- 1- 8	3- 2- 7	4- 3- 5	5- 4- 3	6- 5- 2	7- 6- 0	8- 6-10	9- 7- 8	10- 8- 6
22	1- 0-11	2- 1-11	3- 2-10	4- 3- 9	5- 4- 9	6- 5- 8	7- 6- 7	8- 7- 6	9- 8- 6	10- 9- 5
23	1- 1- 0	2- 2- 1	3- 3- 1	4- 4- 2	5- 5- 2	6- 6- 3	7- 7- 3	8- 8- 4	9- 9- 4	10-10- 5
24	1- 1- 2	2- 2- 3	3- 3- 5	4- 4- 7	5- 5- 8	6- 6-10	7- 7-11	8- 9- 1	9-10- 3	10-11- 4
25	1- 1- 3	2- 2- 6	3- 3- 9	4- 5- 0	5- 6- 2	6- 7- 5	7- 8- 8	8- 9-11	9-11- 2	11- 0- 5
26	1- 1- 4	2- 2- 8	3- 4- 1	4- 5- 5	5- 6- 9	6- 8- 1	7- 9- 5	8-10-10	10- 0- 2	11- 1- 6
27	1- 1- 6	2- 2-11	3- 4- 5	4- 5-11	5- 7- 4	6- 8-10	7-10- 3	8-11- 9	10- 1- 3	11- 2- 8
28	1- 1- 7	2- 3- 2	3- 4- 9	4- 6- 4	5- 7-11	6- 9- 7	7-11- 2	9- 0- 9	10- 2- 4	11- 3-11
29	1- 1- 9	2- 3- 5	3- 5- 2	4- 6-11	5- 8- 7	6-10- 4	8- 0- 1	9- 1- 9	10- 3- 6	11- 5- 2
30	1- 1-10	2- 3- 9	3- 5- 7	4- 7- 5	5- 9- 3	6-11- 2	8- 1- 0	9- 2-10	10- 4- 8	11- 6- 7
31	1- 2- 0	2- 4- 0	3- 6- 0	4- 8- 0	5-10- 0	7- 0- 0	8- 2- 0	9- 4- 0	10- 6- 0	11- 8- 0
32	1- 2- 2	2- 4- 4	3- 6- 5	4- 8- 7	5-10- 9	7- 0-11	8- 3- 1	9- 5- 2	10- 7- 4	11- 9- 6
33	1- 2- 4	2- 4- 7	3- 6-11	4- 9- 3	5-11- 7	7- 1-10	8- 4- 2	9- 6- 6	10- 8- 9	11-11- 1
34	1- 2- 6	2- 4-11	3- 7- 5	4- 9-11	6- 0- 5	7- 2-10	8- 5- 4	9- 7- 9	10-10- 3	12- 0- 9
35	1- 2- 8	2- 5- 4	3- 7-11	4-10- 7	6- 1- 3	7- 3-11	8- 6- 7	9- 9- 2	10-11-10	12- 2- 6
36	1- 2-10	2- 5- 8	3- 8- 6	4-11- 4	6- 2- 2	7- 5- 0	8- 7-10	9-10- 8	11- 1- 6	12- 4- 4

EXAMPLE SHOWING USE

Read the rafter span found at head of this table in feet, in inches, or in
of pitch in the table are to be read as feet, as inches, or as twelfths
have a rafter length of 7 *feet*, for a span of 6 *inches* it has a rafter length of
Then a rafter of 31° pitch to span 6′ 6½″ will have a length of 7–7–7, or, in

DEGREE ROOFING TABLE, GIVING LENGTHS OF

Pitch of roof in degrees.	Span of Rafter.									
	1	2	3	4	5	6	7	8	9	10
12	1- 5- 2	2-10- 4	4- 3- 6	5- 8- 8	7- 1-10	8- 7- 0	10- 0- 1	11- 5- 3	12-10- 5	14- 3- 7
13	1- 5- 2	2-10- 5	4- 3- 7	5- 8- 9	7- 2- 0	8- 7- 2	10- 0- 4	11- 5- 7	12-10- 9	14- 3-11
14	1- 5- 3	2-10- 5	4- 3- 8	5- 8-11	7- 2- 2	8- 7- 4	10- 0- 7	11- 5-10	12-11- 1	14- 4- 3
15	1- 5- 3	2-10- 7	4- 3-10	5- 9- 1	7- 2- 4	8- 7- 8	10- 0-11	11- 6- 2	12-11- 5	14- 4- 9
16	1- 5- 4	2-10- 8	4- 3-11	5- 9- 3	7- 2- 7	8- 7-11	10- 1- 3	11- 6- 6	12-11-10	14- 5- 2
17	1- 5- 4	2-10- 9	4- 4- 1	5- 9- 5	7- 2-10	8- 8- 2	10- 1- 6	11- 6-11	13- 0- 3	14- 5- 8
18	1- 5- 5	2-10-10	4- 4- 3	5- 9- 8	7- 3- 1	8- 8- 6	10- 1-11	11- 7- 4	13- 0- 9	14- 6- 2
19	1- 5- 6	2-10-11	4- 4- 5	5- 9-10	7- 3- 4	8- 8-10	10- 2- 3	11- 7- 9	13- 1- 2	14- 6- 8
20	1- 5- 6	2-11- 1	4- 4- 7	5-10- 1	7- 3- 7	8- 9- 2	10- 2- 8	11- 8- 2	13- 1- 9	14- 7- 3
21	1- 5- 7	2-11- 2	4- 4- 9	5-10- 4	7- 3-11	8- 9- 6	10- 3- 1	11- 8- 8	13- 2- 3	14- 7-10
22	1- 5- 8	2-11- 4	4- 4-11	5-10- 7	7- 4- 3	8- 9-11	10- 3- 7	11- 9- 2	13- 2-10	14- 8- 6
23	1- 5- 9	2-11- 5	4- 5- 2	5-10-11	7- 4- 7	8-10- 4	10- 4- 0	11- 9- 9	13- 3- 6	14- 9- 2
24	1- 5-10	2-11- 7	4- 5- 5	5-11- 2	7- 5- 0	8-10- 9	10- 4- 7	11-10- 5	13- 4- 2	14-10- 0
25	1- 5-10	2-11- 9	4- 5- 7	5-11- 6	7- 5- 4	8-11- 3	10- 5- 1	11-10-11	13- 4-10	14-10- 8
26	1- 5-11	2-11-11	4- 5-10	5-11-10	7- 5- 9	8-11- 8	10- 5- 8	11-11- 7	13- 5- 7	14-11- 6
27	1- 6- 0	3- 0- 1	4- 6- 1	6- 0- 2	7- 6- 2	9- 0- 3	10- 6- 3	12- 0- 4	13- 6- 4	15- 0- 5
28	1- 6- 2	3- 0- 3	4- 6- 5	6- 0- 6	7- 6- 8	9- 0-10	10- 6-11	12- 1- 1	13- 7- 2	15- 1- 4
29	1- 6- 3	3- 0- 5	4- 6- 8	6- 0-11	7- 7- 2	9- 1- 4	10- 7- 7	12- 1-10	13- 8- 1	15- 2- 3
30	1- 6- 4	3- 0- 8	4- 7- 0	6- 1- 4	7- 7- 8	9- 2- 0	10- 8- 4	12- 2- 8	13- 9- 0	15- 3- 4
31	1- 6- 5	3- 0-11	4- 7- 4	6- 1- 9	7- 8- 2	9- 2- 8	10- 9- 1	12- 3- 6	13- 9-11	15- 4- 5
32	1- 6- 7	3- 1- 1	4- 7- 8	6- 2- 3	7- 8- 9	9- 3- 4	10- 9-11	12- 4- 5	13-11- 0	15- 5- 6
33	1- 6- 8	3- 1- 4	4- 8- 0	6- 2- 8	7- 9- 5	9- 4- 1	10-10- 9	12- 5- 5	14- 0- 1	15- 6- 9
34	1- 6-10	3- 1- 7	4- 8- 5	6- 3- 2	7-10- 0	9- 4-10	10-11- 7	12- 6- 5	14- 1- 3	15- 8- 0
35	1- 6-11	3- 1-11	4- 8-10	6- 3- 9	7-10- 8	9- 5- 8	11- 0- 7	12- 7- 6	14- 2- 5	15- 9- 4
36	1- 7- 1	3- 2- 2	4- 9- 3	6- 4- 4	7-11- 5	9- 6- 6	11- 1- 7	12- 8- 8	14- 3- 9	15-10-10

EXAMPLE SHOWING USE

At head of this table read the same span that has already been used for
Then hip and valley lengths given for every degree of roof pitch in the table
Thus a roof pitched at 30° for a rafter span of 6 *feet* has a hip and valley
and 2 *twelfths*, and for a span of 6 *twelfths* has a hip length of 9 *twelfths*. Then
9–11–11, or, in full, 9 feet 11 inches and 11 twelfths.

OF RAFTERS FOR ROOFS OF 12° TO 36° PITCH

Span of Rafter.										Pitch of roof in degrees.
11	12	13	14	15	16	17	18	19	20	
11-2-11	12-3-3	13-3-6	14-3-9	15-4-0	16-4-3	17-4-7	18-4-10	19-5-1	20-5-4	12
11-3-6	12-3-9	13-4-1	14-4-5	15-4-9	16-5-1	17-5-4	18-5-8	19-6-0	20-6-4	13
11-4-1	12-4-5	13-4-9	14-5-2	15-5-6	16-5-11	17-6-3	18-6-7	19-7-0	20-7-4	14
11-4-8	12-5-1	13-5-6	14-5-11	15-6-4	16-6-9	17-7-2	18-7-7	19-8-1	20-8-6	15
11-5-4	12-5-10	13-6-3	14-6-9	15-7-3	16-7-9	17-8-3	18-8-8	19-9-2	20-9-8	16
11-6-0	12-6-7	13-7-2	14-7-8	15-8-3	16-8-9	17-9-4	18-9-10	19-10-5	20-11-0	17
11-6-10	12-7-5	13-8-0	14-8-8	15-9-3	16-9-11	17-10-6	18-11-1	19-11-9	21-0-4	18
11-7-7	12-8-4	13-9-0	14-9-8	15-10-5	16-11-1	17-11-9	19-0-5	20-1-2	21-1-10	19
11-8-6	12-9-3	13-10-0	14-10-9	15-11-7	17-0-4	18-1-1	19-1-10	20-2-8	21-3-5	20
11-9-5	12-10-3	13-11-1	14-11-11	16-0-10	17-1-8	18-2-6	19-3-8	20-4-3	21-5-1	21
11-10-4	12-11-4	14-0-3	15-1-2	16-2-2	17-3-1	18-4-0	19-5-0	20-5-11	21-6-10	22
11-11-5	13-0-5	14-1-6	15-2-6	16-3-7	17-4-7	18-5-7	19-6-8	20-7-8	21-8-9	23
12-0-6	13-1-8	14-2-9	15-3-11	16-5-0	17-6-2	18-7-4	19-8-5	20-9-7	21-10-9	24
12-1-8	13-2-11	14-4-2	15-5-4	16-6-7	17-7-10	18-9-1	19-10-4	20-11-7	22-0-10	25
12-2-10	13-4-3	14-5-7	15-6-11	16-8-3	17-9-7	18-11-0	20-0-4	21-1-8	22-3-0	26
12-4-2	13-5-7	14-7-1	15-8-7	16-10-0	17-11-6	19-0-11	20-2-5	21-3-11	22-5-4	27
12-5-6	13-7-1	14-8-8	15-10-3	16-11-10	18-1-5	19-3-1	20-4-8	21-6-3	22-7-10	28
12-6-11	13-8-8	14-10-4	16-0-1	17-1-10	18-3-6	19-5-3	20-7-0	21-8-8	22-10-5	29
12-8-5	13-10-3	15-0-2	16-2-0	17-3-10	18-5-8	19-7-7	20-9-5	21-11-3	23-1-2	30
12-10-0	14-0-0	15-2-0	16-4-0	17-6-0	18-8-0	19-10-0	21-0-0	22-2-0	23-4-0	31
12-11-8	14-1-10	15-3-11	16-6-1	17-8-3	18-10-5	20-0-7	21-2-8	22-4-10	23-7-0	32
13-1-5	14-3-8	15-6-0	16-8-4	17-10-8	19-0-11	20-3-3	21-5-7	22-7-10	23-10-2	33
13-3-3	14-5-8	15-8-2	16-10-8	18-1-2	19-3-7	20-6-1	21-8-7	22-11-0	24-1-6	34
13-5-2	14-7-10	15-10-5	17-1-1	18-3-9	19-6-5	20-9-0	21-11-8	23-2-4	24-5-0	35
13-7-2	14-10-0	16-0-10	17-3-8	18-6-6	19-9-4	21-0-2	22-3-0	23-5-10	24-8-8	36

OF THIS TABLE.

twelfths, as your span requires. Then rafter lengths given for every degree accordingly. Thus a roof pitched at 31° for a span of 6 *feet* is shown to 7 *inches*, and for a span of 6 *twelfths* (or ½") it has a rafter length of 7 *twelfths*. full, 7 feet 7 inches and 7 twelfths.

HIPS AND VALLEYS FOR ROOFS OF 12° TO 36° PITCH

Span of Rafter.										Pitch of roof in degrees.
11	12	13	14	15	16	17	18	19	20	
15-8-9	17-1-11	18-7-1	20-0-3	21-5-5	22-10-7	24-3-9	25-8-11	27-2-1	28-7-3	12
15-9-2	17-2-4	18-7-6	20-0-9	21-5-11	22-11-2	24-4-4	25-9-6	27-2-8	28-7-11	13
15-9-7	17-2-9	18-8-1	20-1-3	21-6-6	22-11-9	24-5-0	25-10-3	27-3-5	28-8-8	14
15-10-0	17-3-3	18-8-7	20-1-10	21-7-1	23-0-4	24-5-8	25-10-11	27-4-2	28-9-5	15
15-10-6	17-3-10	18-9-1	20-2-5	21-7-9	23-1-1	24-6-5	25-11-8	27-5-0	28-10-4	16
15-11-0	17-4-4	18-9-9	20-3-1	21-8-5	23-1-10	24-7-2	26-0-6	27-5-11	28-11-3	17
15-11-7	17-4-11	18-10-4	20-3-9	21-9-2	23-2-7	24-8-0	26-1-5	27-6-10	29-0-3	18
16-0-2	17-5-9	18-11-1	20-4-6	21-10-0	23-3-5	24-8-11	26-2-5	27-7-10	29-1-4	19
16-0-9	17-6-3	18-11-10	20-5-4	21-10-10	23-4-5	24-9-11	26-3-5	27-8-11	29-2-6	20
16-1-5	17-7-2	19-0-7	20-6-2	21-1-9	23-5-4	24-10-10	26-4-6	27-10-1	29-3-8	21
16-2-2	17-7-10	19-1-5	20-7-1	22-0-9	23-6-5	25-0-0	26-5-8	27-11-4	29-5-0	22
16-2-11	17-8-8	19-2-4	20-8-1	22-1-9	23-7-6	25-1-3	26-6-11	28-0-8	29-6-5	23
16-3-8	17-9-6	19-3-4	20-9-1	22-2-11	23-8-8	25-2-6	26-8-3	28-2-1	29-7-10	24
16-4-7	17-10-5	19-4-4	20-10-2	22-4-0	23-9-11	25-3-9	26-9-8	28-3-6	29-9-5	25
16-5-6	17-11-5	19-5-4	20-11-4	22-5-3	23-11-3	25-5-2	26-11-2	28-5-1	29-11 0	26
16-6-5	18-0-6	19-6-6	21-0-6	22-6-7	24-0-7	25-6-8	27-0-8	28-6-9	30-0-9	27
16-7-6	18-1-7	19-7-9	21-1-11	22-8-0	24-2-2	25-8-3	27-2-5	28-8-7	30-2-8	28
16-8-6	18-2-9	19-8-11	21-3-2	22-9-5	24-3-8	25-9-10	27-4-1	28-10-4	30-4-7	29
16-9-8	18-4-0	19-10-4	21-4-8	22-11-0	24-5-4	25-11-8	27-6-0	29-0-4	30-6-8	30
16-10-10	18-5-3	19-11-8	21-6-2	23-0-7	24-7-0	26-1-6	27-7-11	29-2-4	30-8-9	31
17-0-1	18-6-8	20-1-2	21-7-9	23-2-4	24-8-10	26-3-5	27-10-0	29-4-6	30-11-1	32
17-1-5	18-8-1	20-2-9	21-9-5	23-4-1	24-10-9	26-5-5	28-0-2	29-6-10	31-1-6	33
17-2-10	18-9-8	20-4-5	21-11-3	23-6-0	25-0-10	26-7-8	28-2-5	29-9-3	31-4-1	34
17-4-4	18-11-3	20-6-2	22-1-1	23-8-1	25-3-0	26-9-11	28-4-10	29-11-10	31-6-9	35
17-5-10	19-0-11	20-8-0	22-3-1	23-10-2	25-5-3	27-0-4	28-7-5	30-2-6	31-9-7	36

OF THIS TABLE.

the rafter pattern, in feet, in inches, or in twelfths, as your span requires. are also to be read in feet, in inches, or in twelfths accordingly. length of 9 *feet 2 inches*, for a span of 6 *inches* has a hip length of 9 *inches* for the 30° pitch when the rafter spans 6′ 6½″ hip and valley length will be

DEGREE ROOFING TABLE, GIVING LENGTHS OF

Pitch of roof in degrees.	Span of Rafter. 1	2	3	4	5	6	7	8	9	10
37	1-3-0	2-6-1	3-9-1	5-0-1	6-3-2	7-6-2	8-9-2	10-0-3	11-3-3	12-6-3
38	1-3-3	2-6-5	3-9-8	5-0-11	6-4-2	7-7-4	8-10-7	10-1-10	11-5-1	12-8-3
39	1-3-5	2-6-11	3-10-4	5-1-9	6-5-2	7-8-8	9-0-1	10-3-6	11-7-0	12-10-5
40	1-3-8	2-7-4	3-11-0	5-2-8	6-6-4	7-10-0	9-1-8	10-5-4	11-9-0	13-0-8
41	1-3-11	2-7-10	3-11-8	5-3-7	6-7-6	7-11-5	9-3-4	10-7-2	11-11-1	13-3-0
42	1-4-2	2-8-4	4-0-5	5-4-7	6-8-9	8-0-11	9-5-0	10-9-2	12-1-4	13-5-6
43	1-4-5	2-8-10	4-1-3	5-5-8	6-10-0	8-2-5	9-6-10	10-11-3	12-3-8	13-8-1
44	1-4-8	2-9-4	4-2-1	5-6-9	6-11-5	8-4-1	9-8-9	11-1-5	12-6-2	13-10-10
45	1-5-0	2-9-11	4-2-11	5-7-11	7-0-10	8-5-10	9-10-10	11-3-9	12-8-9	14-1-8
46	1-5-3	2-10-7	4-3-10	5-9-1	7-2-5	8-7-8	10-0-11	11-6-2	12-11-6	14-4-9
47	1-5-7	2-11-2	4-4-9	5-10-5	7-4-0	8-9-7	10-3-2	11-8-9	13-2-4	14-7-11
48	1-5-11	2-11-10	4-5-10	5-11-9	7-5-8	8-11-7	10-5-6	11-11-6	13-5-5	14-11-4
49	1-6-4	3-0-7	4-6-11	6-1-2	7-7-5	9-1-9	10-8-0	12-2-4	13-8-7	15-2-11
50	1-6-8	3-1-4	4-8-0	6-2-8	7-9-4	9-4-0	10-10-8	12-5-4	14-0-0	15-6-8
51	1-7-1	3-2-2	4-9-2	6-4-3	7-11-4	9-6-5	11-1-6	12-8-7	14-3-7	15-10-8
52	1-7-6	3-3-0	4-10-6	6-6-0	8-1-5	9-8-11	11-4-5	12-11-11	14-7-5	16-2-11
53	1-7-11	3-3-11	4-11-10	6-7-9	8-3-8	9-11-8	11-7-7	13-3-6	14-11-5	16-7-5
54	1-8-5	3-4-10	5-1-3	6-9-8	8-6-1	10-2-6	11-10-11	13-7-4	15-3-9	17-0-2
55	1-8-11	3-5-10	5-2-9	6-11-8	8-8-7	10-5-6	12-2-5	13-11-5	15-8-4	17-5-3
56	1-9-6	3-6-11	5-4-5	7-1-10	8-11-4	10-8-9	12-6-3	14-3-8	16-1-2	17-10-7
57	1-10-0	3-8-1	5-6-1	7-4-2	9-2-2	11-0-2	12-10-3	14-8-3	16-6-4	18-4-4
58	1-10-8	3-9-3	5-7-11	7-6-7	9-5-3	11-3-10	13-2-6	15-1-2	16-11-10	18-10-5
59	1-11-4	3-10-7	5-9-11	7-9-2	9-8-6	11-7-9	13-7-1	15-6-5	17-5-8	19-5-0
60	2-0-0	4-0-0	6-0-0	8-0-0	10-0-0	12-0-0	14-0-0	16-0-0	18-0-0	20-0-0
61	2-0-9	4-1-6	6-2-3	8-3-0	10-3-9	12-4-6	14-5-3	16-6-0	18-6-9	20-7-6

EXAMPLE SHOWING USE

Read the rafter span found at head of this table in feet, in inches, or in
or pitch in the table are to be read as feet, as inches, or as twelfths
a rafter length of 9 *feet* 4 *inches*, for a span of 6 *inches* it has a rafter length
⅜". Then a rafter of 50° pitch that is to span 6′ 6½" is seen to have a rafter

DEGREE ROOFING TABLE, GIVING LENGTHS OF

Pitch of roof in degrees.	Span of Rafter. 1	2	3	4	5	6	7	8	9	10
37	1-7-3	3-2-5	4-9-8	6-4-11	8-0-2	9-7-5	11-2-7	12-9-10	14-5-1	16-0-4
38	1-7-5	3-2-9	4-10-2	6-5-7	8-0-11	9-8-4	11-3-9	12-11-1	14-6-6	16-1-11
39	1-7-7	3-3-1	4-10-8	6-6-3	8-1-9	9-9-4	11-4-11	13-0-5	14-8-0	16-3-7
40	1-7-9	3-3-6	4-11-2	6-6-11	8-2-8	9-10-5	11-6-2	13-1-10	14-9-7	16-5-4
41	1-7-11	3-3-10	4-11-9	6-7-8	8-3-7	9-11-6	11-7-5	13-3-5	14-11-4	16-7-3
42	1-8-1	3-4-3	5-0-4	6-8-6	8-4-7	10-0-8	11-8-10	13-4-11	15-1-1	16-9-2
43	1-8-4	3-4-8	5-1-0	6-9-4	8-5-8	10-2-0	11-10-4	13-6-8	15-2-11	16-11-3
44	1-8-7	3-5-1	5-1-8	6-10-2	8-6-9	10-3-4	11-11-10	13-8-5	15-4-11	17-1-6
45	1-8-9	3-5-7	5-2-4	6-11-2	8-7-11	10-4-8	12-1-6	13-10-3	15-7-1	17-3-10
46	1-9-0	3-6-1	5-3-1	7-0-2	8-9-2	10-6-2	12-3-3	14-0-3	15-9-4	17-6-4
47	1-9-4	3-6-7	5-3-11	7-1-2	8-10-6	10-7-9	12-5-1	14-2-5	15-11-8	17-9-0
48	1-9-7	3-7-2	5-4-9	7-2-4	8-11-11	10-9-6	12-7-1	14-4-8	16-6-2	17-11-9
49	1-9-11	3-7-9	5-5-8	7-3-6	9-1-5	10-11-3	12-9-2	14-7-0	16-4-11	18-2-9
50	1-10-2	3-8-5	5-6-7	7-4-9	9-3-0	11-1-2	12-11-4	14-9-7	16-7-9	18-5-11
51	1-10-6	3-9-1	5-7-7	7-6-1	9-4-8	11-3-2	13-1-8	15-0-3	16-10-9	18-9-4
52	1-10-11	3-9-9	5-8-8	7-7-7	9-6-5	11-5-4	13-4-3	15-3-1	17-2-0	19-0-11
53	1-11-3	3-10-7	5-9-10	7-9-1	9-8-4	11-7-8	13-6-11	15-6-2	17-5-5	19-4-9
54	1-11-8	3-11-4	5-11-1	7-10-9	9-10-5	11-10-1	13-9-9	15-9-5	17-9-2	19-8-10
55	2-0-2	4-0-3	6-0-4	8-0-6	10-0-7	12-0-9	14-0-10	16-0-11	18-1-1	20-1-2
56	2-0-7	4-1-2	6-1-9	8-2-4	10-2-11	12-3-6	14-4-1	16-4-8	18-5-3	20-5-10
57	2-1-1	4-2-2	6-3-3	8-4-4	10-5-5	12-6-6	14-7-8	16-8-9	18-9-10	20-10-11
58	2-1-8	4-3-3	6-4-11	8-6-6	10-8-2	12-9-9	14-11-5	17-1-0	19-2-8	21-4-3
59	2-2-2	4-4-5	6-6-8	8-8-10	10-11-0	13-1-3	15-3-5	17-5-8	19-7-11	21-10-1
60	2-2-10	4-5-8	6-8-6	8-11-4	11-2-2	13-5-0	15-7-10	17-10-8	20-1-6	22-4-4
61	2-3-6	4-7-0	6-10-6	9-2-10	11-5-6	13-9-1	16-0-7	18-4-1	20-7-7	22-11-1

EXAMPLE SHOWING USE

At head of this table read the same rafter span that has already been used
hip and valley lengths given for every degree of roof pitch in the table
roof pitched at 43°, for a rafter span of 6 *feet*, has a hip and valley length of
2 *twelfths*, and for a half-inch span has a rafter length of 10 *twelfths*. Then
11-1-0, or, in full, 11 feet and 1 inch.

RAFTERS FOR ROOFS OF 37° TO 61° PITCH

Span of Rafter. 11	12	13	14	15	16	17	18	19	20	Pitch of roof in degrees.
13- 9- 3	15- 0- 4	16- 3- 4	17- 6- 4	18- 9- 5	20- 0- 5	21- 3- 5	22- 6- 6	23- 9- 6	25- 0- 6	37
13-11- 6	15- 2- 9	16- 6- 0	17- 9- 2	19- 0- 5	20- 3- 8	21- 6-11	22-10- 1	24- 1- 4	25- 4- 7	38
14- 1-10	15- 5- 4	16- 8- 9	18- 0- 2	19- 3- 7	20- 7- 1	21-10- 6	23- 1-11	24- 5- 5	25- 8-10	39
14- 4- 4	15- 8- 0	16-11- 8	18- 3- 4	19- 7- 0	20-10- 8	22- 2- 4	23- 6- 0	24- 9- 8	26- 1- 4	40
14- 6-11	15-10-10	17- 2- 8	18- 6- 7	19-10- 6	21- 2- 5	22- 6- 4	23-10- 2	25- 2- 1	26- 6- 0	41
14- 9- 8	16- 1-10	17- 5-11	18-10- 1	20- 2- 3	21- 6- 4	22-10- 6	24- 2- 8	25- 6-10	26-10-11	42
15- 0- 6	16- 4-11	17- 9- 4	19- 1- 9	20- 6- 1	21-10- 6	23- 2-11	24- 7- 4	25-11- 9	27- 4- 2	43
15- 3- 6	16- 8- 2	18- 0-10	19- 5- 7	20-10- 3	22- 2-11	23- 7- 7	25- 0- 3	26- 4-11	27- 9- 8	44
15- 6- 8	16-11- 8	18- 4- 7	19- 9- 7	21- 2- 7	22- 7- 6	24- 0- 6	25- 5- 6	26-10- 5	28- 3- 5	45
15-10- 0	17- 3- 4	18- 8- 7	20- 1-10	21- 7- 2	23- 0- 5	24- 5- 8	25-10-11	27- 4- 3	28- 9- 6	46
16- 1- 7	17- 7- 2	19- 0- 9	20- 6- 4	21-11-11	23- 5- 6	24-11- 2	26- 4- 9	27-10- 4	29- 3-11	47
16- 5- 3	17-11- 2	19- 5- 2	20-11- 1	22- 5- 0	23-10-11	25- 4-11	26-10-10	28- 4- 9	29-10- 8	48
16- 9- 2	18- 3- 6	19- 9- 9	21- 4- 1	22-10- 4	24- 4- 8	25-10-11	27- 5- 3	28-11- 6	30- 5-10	49
17- 1- 4	18- 8- 0	20- 2- 8	21- 9- 4	23- 4- 0	24-10- 8	26- 5- 4	28- 0- 0	29- 6- 8	31- 1- 5	50
17- 5- 9	19- 0-10	20- 7-11	22- 2-11	23-10- 0	25- 5- 1	27- 0- 2	28- 7- 3	30- 2- 4	31- 9- 4	51
17-10- 5	19- 5-11	21- 1- 5	22- 8-11	24- 4- 4	25-11-10	27- 7- 4	29- 2-10	30-10- 4	32- 5-10	52
18- 3- 4	19-11- 3	21- 7- 3	23- 3- 2	24- 11-1	26- 5- 0	28- 3- 0	29-10-11	31- 6-10	33- 2- 9	53
18- 8- 7	20- 5- 0	22- 1- 5	23- 9-10	25- 6- 3	27- 2- 8	28-11- 1	30- 7- 6	32- 3-11	34- 0- 4	54
19- 2- 2	20-11- 1	22- 8- 0	24- 4-11	26- 1-10	27-10- 9	29- 7- 8	31- 4- 7	33- 1- 6	34-10- 5	55
19- 8- 1	21- 5- 6	23- 3- 0	25- 0- 5	26- 9-11	28- 7- 4	30- 4-10	32- 2- 3	33-11- 9	35- 9- 2	56
20- 2- 5	22- 0- 5	23-10- 5	25- 8- 6	27- 6- 6	29- 4- 7	31- 2- 7	33- 0- 7	34-10- 8	36- 8- 8	57
20- 9- 1	22- 7- 9	24- 6- 5	26- 5- 0	28- 3- 8	30- 2- 4	32- 1- 0	33-11- 7	35-10- 3	37- 8-11	58
21- 4- 3	23- 3- 7	25- 2-11	27- 2- 2	29- 1- 6	31- 0- 9	33- 0- 1	34-11- 4	36-10- 8	38-10- 0	59
22- 0- 0	24- 0- 0	26- 0- 0	28- 0- 0	30- 0- 0	32- 0- 0	34- 0- 0	36- 0- 0	38- 0- 0	40- 0- 0	60
22- 8- 3	24- 9- 0	26- 9- 9	28-10- 6	30-11- 3	33- 0- 0	35- 0- 9	37- 1- 6	39- 2- 3	41- 3- 0	61

OF THIS TABLE.

twelfths, as your span requires. Then rafter lengths given for every degree accordingly. Thus a roof pitched at 50°, for a span of 6 *feet* is shown to have of 9 *inches* and 4 *twelfths*, and for a half-inch span will have a rafter length of ength of 10-2-1, or, in full, 10 feet 2 inches and 1 twelfth.

HIPS AND VALLEYS FOR ROOFS OF 37° TO 61° PITCH

Span of Rafter. 11	12	13	14	15	16	17	18	19	20	Pitch of roof in degrees.
17- 7- 6	19- 2- 9	20-10- 0	22- 5- 3	24- 0- 5	25- 7- 8	27- 2-11	28-10- 2	30- 5- 4	32- 0- 7	37
17- 9- 3	19- 4- 8	21- 0- 1	22- 7- 5	24- 2-10	25-10- 3	27- 5- 7	29- 1- 0	30- 8- 5	32- 3- 9	38
17-11- 1	19- 6- 8	21- 2- 3	22- 9- 9	24- 5- 4	26- 0-11	27- 8- 5	29- 4- 0	30-11- 7	32- 7- 1	39
18- 1- 1	19- 8-10	21- 4- 6	23- 0- 3	24- 8- 0	26- 3- 9	27-11- 5	29- 7- 2	31- 2-11	32-10- 8	40
18- 3- 2	19-11- 1	21- 7- 0	23- 2-11	24-10-10	26- 6- 9	28- 2- 8	29-10- 7	31- 6- 6	33- 2- 5	41
18- 5- 2	20- 1- 5	21- 9- 6	23- 5- 8	25- 1- 9	26- 9-11	28- 6- 0	30- 2- 2	31-10- 3	33- 6- 4	42
18- 7- 7	20- 3-11	22- 0- 2	23- 8- 7	25- 4-11	27- 1- 3	28- 9- 7	30- 5- 1	32- 2- 3	33-10- 7	43
18-10- 1	20- 6- 7	22- 3- 2	23-11- 8	25- 8- 3	27- 4-10	29- 1- 4	30- 9-11	32- 6- 5	34- 3- 0	44
19- 0- 8	20- 9- 5	22- 6- 2	24- 3- 0	25-11- 9	27- 8- 7	29- 5- 4	31- 2- 2	32-10-11	34- 7- 8	45
19- 3- 4	21- 0- 5	22- 9- 5	24- 6- 6	26- 3- 6	28- 0- 6	29- 9- 7	31- 6- 7	33- 3- 8	35- 0- 8	46
19- 6- 3	21- 3- 7	23- 0-11	24-10- 2	26- 7- 6	28- 4- 9	30- 2- 1	31-11- 4	33- 8- 8	35- 5-11	47
19- 9- 4	21- 6-11	23- 6- 6	25- 2- 1	26-11- 8	28- 9- 3	30- 6-10	32- 4- 5	34- 2- 0	35-11- 7	48
20- 0- 8	21-10- 6	23- 8- 5	25- 6- 3	27- 4- 2	29- 2- 0	30-11-11	32- 9- 9	34- 7- 8	36- 5- 6	49
20- 4- 2	22- 2- 4	24- 0- 6	25-10- 8	27- 8-11	29- 7- 1	31- 5- 3	33- 3- 6	35- 1- 8	36-11-10	50
20- 7-10	22- 6- 4	24- 4- 4	26- 3- 5	28- 1-11	30- 0- 6	31-11- 0	33- 9- 6	35- 8- 1	37- 6- 7	51
20-11- 9	22-10- 8	24- 9- 7	26- 8- 5	28- 7- 4	30- 6- 3	32- 5- 1	34- 4- 0	36- 2-11	38- 1- 9	52
21- 4- 0	23- 3- 3	25- 2- 6	27- 1-10	29- 1- 1	31- 0- 4	32-11- 8	34-10-11	36-10- 2	38- 9- 5	53
21- 8- 6	23- 8- 2	25- 7-10	27- 7- 6	29- 7- 3	31- 6-11	33- 6- 7	35- 6- 3	37- 5-11	39- 5- 8	54
22- 1- 4	24- 1- 5	26- 1- 7	28- 1- 8	30- 1- 9	32- 1-11	34- 2- 0	36- 2- 2	38- 2- 3	40- 2- 5	55
22- 6- 5	24- 7- 1	26- 7- 8	28- 8- 3	30- 8-10	32- 9- 5	34-10- 0	36-10- 7	38-11- 2	40-11- 9	56
23- 0- 0	25- 1- 1	27- 2- 2	29- 3- 3	31- 4- 4	33- 5- 5	35- 6- 6	37- 7- 7	39- 8- 8	41- 9- 9	57
23- 5-11	25- 7- 6	27- 9- 2	29-10-10	32- 0- 5	34- 2- 1	36- 3- 8	38- 5- 4	40- 6-11	42- 8- 7	58
24- 0- 3	26- 2- 6	28- 4- 8	30- 6-11	32- 9- 2	34-11- 4	37- 1- 6	39- 3- 9	41- 5-11	43- 8- 2	59
24- 7- 2	26-10- 0	29- 0-10	31- 3- 8	33- 6- 6	35- 9- 4	38- 0- 2	40- 3- 0	42- 5-10	44- 8- 8	60
25- 2- 7	27- 6- 1	29- 9- 7	31- 1- 1	34- 4- 7	36- 8- 2	38-11- 8	41- 3- 2	43- 6- 8	45-10- 2	61

OF THIS TABLE

for the rafter, in feet, in inches, or in twelfths, as your span requires. Then are also to be read in feet, in inches, or in twelfths accordingly. Thus a 10 *feet* 2 *inches*, for a span of 6 *inches* it has a hip length of 10 *inches* and for the 43° pitch, when the rafter spans 6′ 6½″, hip and valley length will be

The set of tables on pp. 120–125 have been compiled for purposes of ready reference and for doing away with the necessity for elaborate calculations. They are calculated for spans of from 1 foot to 20 feet, but obviously by simple addition of the figures in two or more of the appropriate columns data can be obtained for much greater spans. Another set of tables gives the length of rafters for roof pitches of from 12° to 36°. The method of using them is sufficiently explained in the footnotes. But these tables can be applied to other problems; for instance, estimating for roof boards, roofing felt, tiles, or slates. The usual way is to measure off every individual face of every part of a roof, dormer, etc., and add up the different areas. Equally accurate and much quicker results will follow by the use of these tables. The area plan of the roof can be measured off in feet, in squares, or other convenient unit. Now, having the roof pitch, we look up on the table the rafter length for 1 span, and multiply the plan area by this rafter length. However many hips, valleys, breaks, and gables the building may have, the result of the operation will be the area of all the roof slopes, and so give the quantity of materials needed, due allowances being made for gauges and laps. By way of illustration, let us say that the roof plan measures up to 24 squares, and its pitch is 52°. The rafter length for 1 foot is 1–7–6. Multiplying 24 and 1–7–6 we have 37–10–0, or about 38 squares as area of the roof coverings.

BRACE MEASURES

On the back of the tongue, along the centre, is a brace scale, giving the lengths of braces in a roof of stated size and run (*i.e.* the length of the hypotenuse of a triangle with equal sides). Thus: if the rise and run are 30 inches then the table shows that the length of the brace will be $42\frac{43}{100}$ inches.

Usually, on the back of the tongue, near the angle with the blade, is also found a diagonal scale marking off hundredths of an inch. The horizontal lines are 1 foot long, and are divided into ten sections horizontally, these being crossed by ten diagonal lines.

BOARD MEASURE

On the front of the blade a building board measure scale is scored. It can be used in several ways. If it is required to find the number of board feet (or feet super) in a board 5 inches × 1 inch × 13 feet, then under the mark 12 find the number 13 (for feet) and follow horizontally until the 5-inch mark is reached; the result will be found to be $5\frac{5}{12}$ feet. Should the length be greater than any number found under the mark 12, it will be necessary to make two or more calculations, adding the respective results obtained. The figure 12 represents a 1-inch board 12 inches wide, and is taken as a standard, or starting-point.

POLYGON CUTS

On the front of the tongue is a scale for polygons, usually from 5- to 12-sided figures. This is how the scale is used. If we want a pentagon

we find the figures 18·13⅛ set down for the five-sided figure. This means that 18 is to be taken on the blade and 13⅛ on the tongue. The figures for an octagon are 18·7½, that is, 18 on the blade and 7½ on the tongue. By placing the steel square on the timber or other material the angles can at once be marked off. Halvings and mitre cuts can be obtained quite as easily as shown in the table below.

POLYGON BEVELS AND MITRES

Name of Polygon.	No. of sides.	Halving bevel is 12 on tongue and	Mitre cut is 12 on tongue and	Polygon hip run figure is
Pentagon . . .	5	4–11	8–9	1–2–0
Hexagon . . .	6	6–11	6–11	1–1–10
Heptagon . . .	7	9–11	5–9	1–1–4
Octagon . . .	8	1–0–0	5–0	1–1–0
Nonagon . . .	9	1–2–4	4–5	1–0–9
Decagon . . .	10	1–4–6	3–11	1–0–8
Undecagon . . .	11	1–6–8	3–6	1–0–6
Dodecagon . . .	12	1–8–9	3–3	1–0–5

In addition to giving cuts, the halving column gives the angle by which each successive side of a polygon breaks away from the straight line contained from its edge outside. The mitre cut figures also give two other useful things. First, the figure to use on the tongue while rafter length is used on blades to give jack splays for any of these regular polygons, secondly the length of sides for a polygon of 1-foot radius. Then if we multiply the required diameter of any polygon by these figures we obtain the length to which are cut its sides.

For roofing any of the given polygons, to obtain hip or valley cuts, the roof rise figure on the blade and the hip run figures on the tongue are used. The distance across the square between these points shows hip or valley length for 1 foot of rafter span. Mitres and hip runs for other degrees may be had from the Degree Roofing Tables (pp. 122–125). With 12 on tongue and rise figures for any number of degrees on blade, the steel square will lay off this angle.

ATTACHMENTS

Various attachments may be used in connection with a steel square. The most commonly met with is an adjustable fence. This is merely a strip of hardwood, about 2 inches wide, 1½ inches thick, and 2½ feet long. A saw kerf, long and wide enough for the square to slide, is cut at both ends, leaving about 8 inches of solid wood in the middle. The steel square is clamped to this in the manner desired, so that the fence can rest against the edge of the material, allowing the triangular part of the tool to project, and so placed against the material for marking off. This simple device lends itself to accuracy and expedition. Then there are metal stair gauges, also to be clamped on, and levels by means of which the steel square can be converted into a 2-foot steel plumb and level.

CHAPTER 6

TIMBER-FRAMED BUILDINGS

The traditional types of timber frame are illustrated in Fig. 74. They are now obsolete except in imitation work, but as many old timber cottages and houses in this country are still in use, and builders are called upon to repair and alter them, it is desirable to understand the constructional principles.

Half-timber work is the name given to external walling in which the

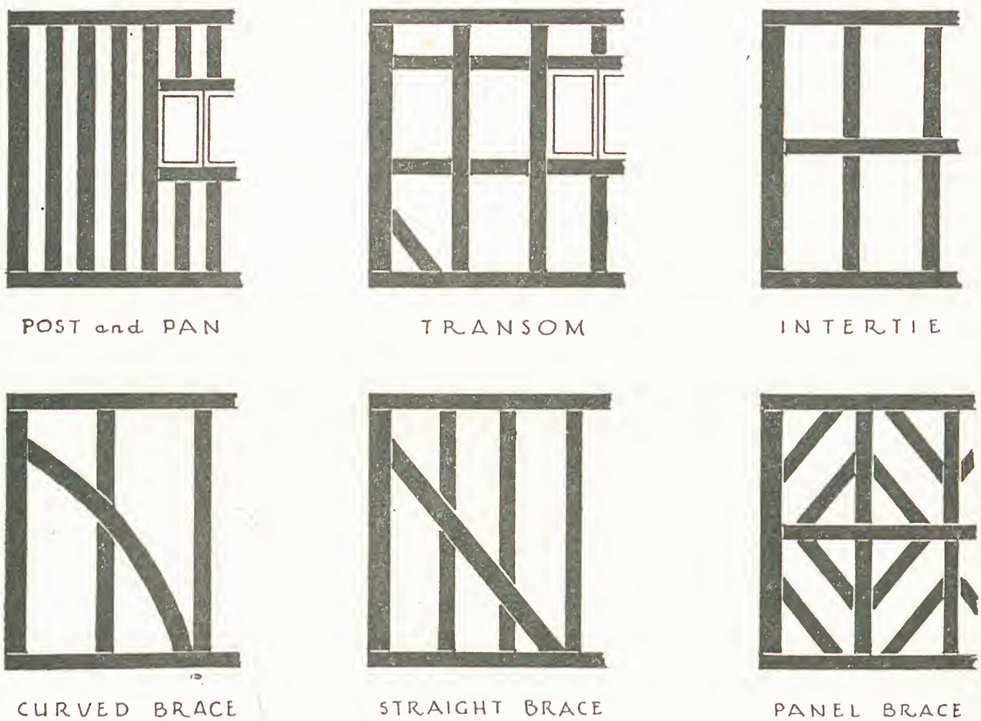


Fig. 74.—Traditional timber framing.

timber framing constitutes the supporting members of the structure, any brickwork or plaster in between being in the nature of a filling rather than structural. The term is rather misleading, as it is suggestive of that form of modern imitation half-timbered work which consists of fixing flat boards, having no structural value, on the face of the supporting walls. A better name would be Timber-frame Construction, as that, in fact,

is what it is, and was the customary method of constructing buildings from Saxon times until the seventeenth century.

Old Construction.—The method of construction consists of laying a beam 12 × 12 inches on a low foundation wall at floor level. Corner and intermediate posts are tenoned into this, and a 6 × 12-inch to 12 × 12-inch beam is fixed across the heads of these posts tenoned into its underside. The spaces between the posts are filled with 8 × 5-inch studs from 8 inches to 12 inches apart, also tenoned at the bottom and chase mortised at the top. This is known as "post and pan" framing, but later the studs were placed wider apart and short horizontal nogging or transom pieces introduced to stiffen the frame.

This method of construction enables the upper storeys to be projected beyond the face of the lower walls by running the floor joists out, either as cantilevers, or supporting them with cut brackets. On the ends of the joists or on a supporting beam are raised similar, though sometimes lighter, posts and intermediate framing with a head run across their tops to form the upper storey. If the building has a third storey the same projecting method is adopted as for that in the old-time buildings; but this, though quite sound construction, would not be permitted by modern bye-laws.

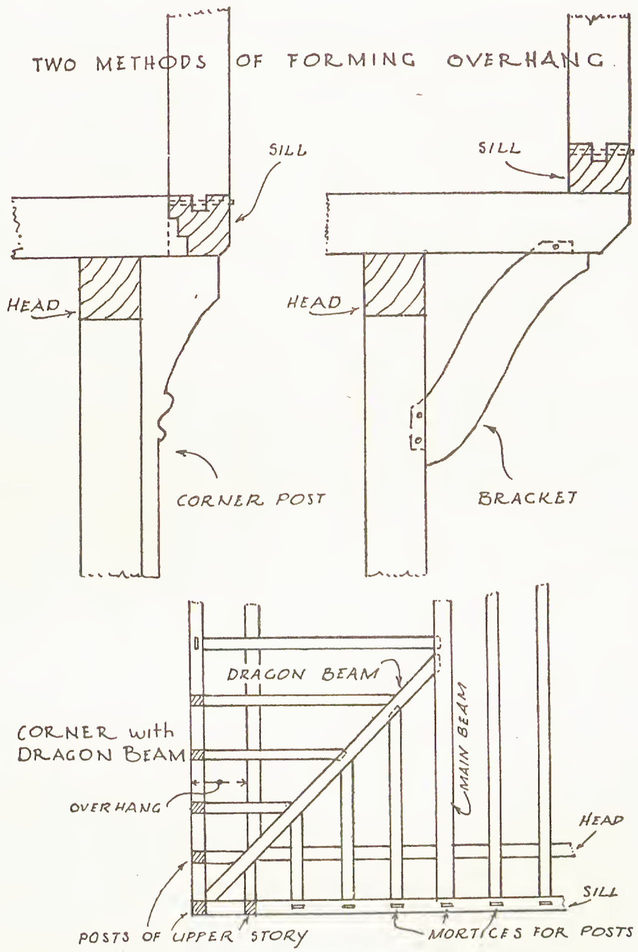


Fig. 75.—Overhanging floors in traditional timber-framed buildings.

The angle posts were stiffened by braces, often curved and irregular, but soundly constructed with pinned mortise and tenons. These and many of the beams were naturally shaped, trimmed tree-trunks or branches.

The original method of filling in the spaces between the timbers consisted of an improved wattle and daub, formed of chopped straw and clay covered with plaster. In later work brick nogging was substituted for this. Very elaborate carving was executed on some of this old-time beam and post work, and the plaster panels were also elaborately decorative.

After the seventeenth century many buildings were completely covered on the exterior with a stucco, and in consequence much fine half-timber construction was hidden from view.

In modern half-timber construction proper, *i.e.* that in which the timber framing actually supports the floors and roof, the timber used

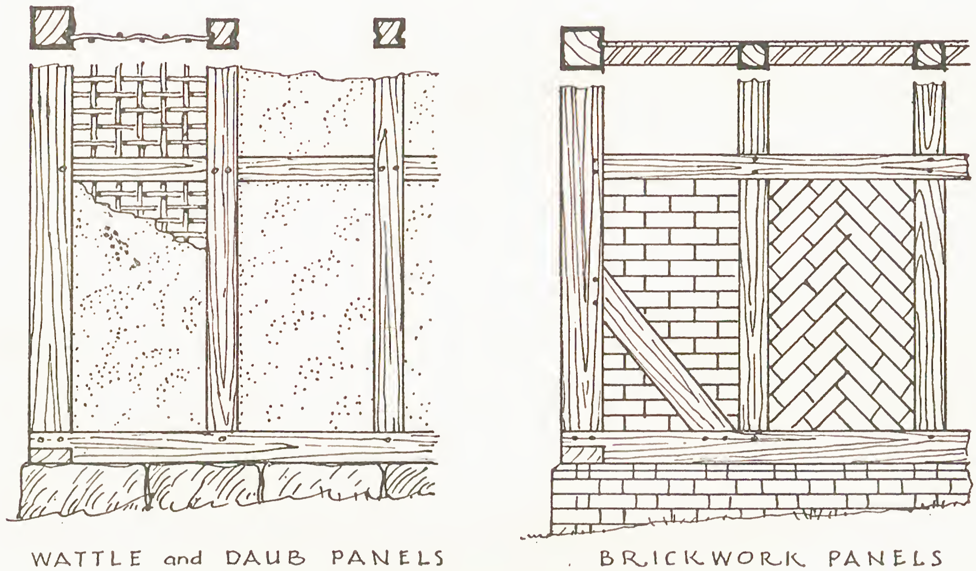


Fig. 76.—Panel fillings in traditional timber-framed buildings.

should be oak, and where exposed it is left from the saw, though adze or rough axe markings are considered more artistic and true to type.

Modern Construction.—The sills and plates are halved at the angles and pinned by the stub tenon cut on the angle post, and the other timbers should be halved and pinned with cleft oak pins, left projecting, not for artistic effect, as is sometimes thought, but to be driven in when required, due to the drying out of the big timbers.

The filling between the timbers is specified in most bye-laws to be of brick or other solid and incombustible materials; and that a thickness of at least $4\frac{1}{2}$ inches of brickwork or other solid and incombustible material shall be placed at the back of every portion of timber, and properly bonded to the brickwork filling the spaces between the timbers.

In a modern building the half timbering is constructed of the following sizes—sill 12×6 inches, head 9×6 inches, intertie 6×6 inches, corner

posts 6 × 6 inches, and carved braces 6 inches thick. The horizontal members are secretly jointed, and have inside the angle an angle strap 2 × $\frac{1}{2}$ inch and 24 inches long bolted with four 6 × $\frac{3}{4}$-inch coach bolts.

When the filling is plaster, the timbers are chamfered and V grooved, and have 2 × 2-inch rough fillets nailed on their sides to receive the lathing. On the back of these fillets is nailed 2-ply or waterproof building paper.

MODERN TIMBER FRAMING

Modern timber framing for houses, bungalows, and other small buildings consists of vertical studs, usually 4 × 2 inches, framed to sill and head plates. The corners are strengthened with extra or heavier posts, plates are arranged to take floor joists, and transom pieces to trim for window and door openings.

The modern systems of site construction described below have been used for some years, chiefly in America and the Scandinavian countries. They are sound and economical, but in recent years new systems suitable for prefabrication have been introduced. These are described in Chapter 9, Volume IV.

Modern Framing.—The recognised systems are :

1. The Braced Frame.
2. The Balloon Frame.
3. The Platform Frame.
4. The Unit Frame.

The Braced Frame is an early type. As will be seen from Fig. 77 the studs run from approximately floor to ceiling so that to a two-floor house there are two sets of studs. The diagonal braces at the corners are a feature of this type of frame. They prevent racking. Ordinary carpentry methods and joints are used in building up these frames.

The Balloon Frame is an American type. The studs run from ground floor to roof, girts or stringers being fixed to take bedroom floor joists. There is no bracing in the frame, but diagonal under-boarding is nailed across the studding and this, of course, stiffens the framing and prevents racking. The weather boarding or other exterior cladding is nailed over the diagonal boarding and waterproof building paper or felt is interleaved between the two sets of boarding. This system is simpler and in some ways better than the braced frame. (See Fig. 78.)

The Platform Frame is the type widely used in this country for site construction. The studded walls of each floor are separate. The ground floor forms a platform on which the lower framing is erected. The bedroom floor is then added and in turn forms a platform for the upper framing. (See Fig. 79.)

The Unit Frame is a recently introduced type which is partly prefabricated. A skeleton frame is erected and small panel frames fitted to it, the latter being fabricated in the workshop. (See Fig. 80.)

In all the above systems the timbers can be cut in the workshop,

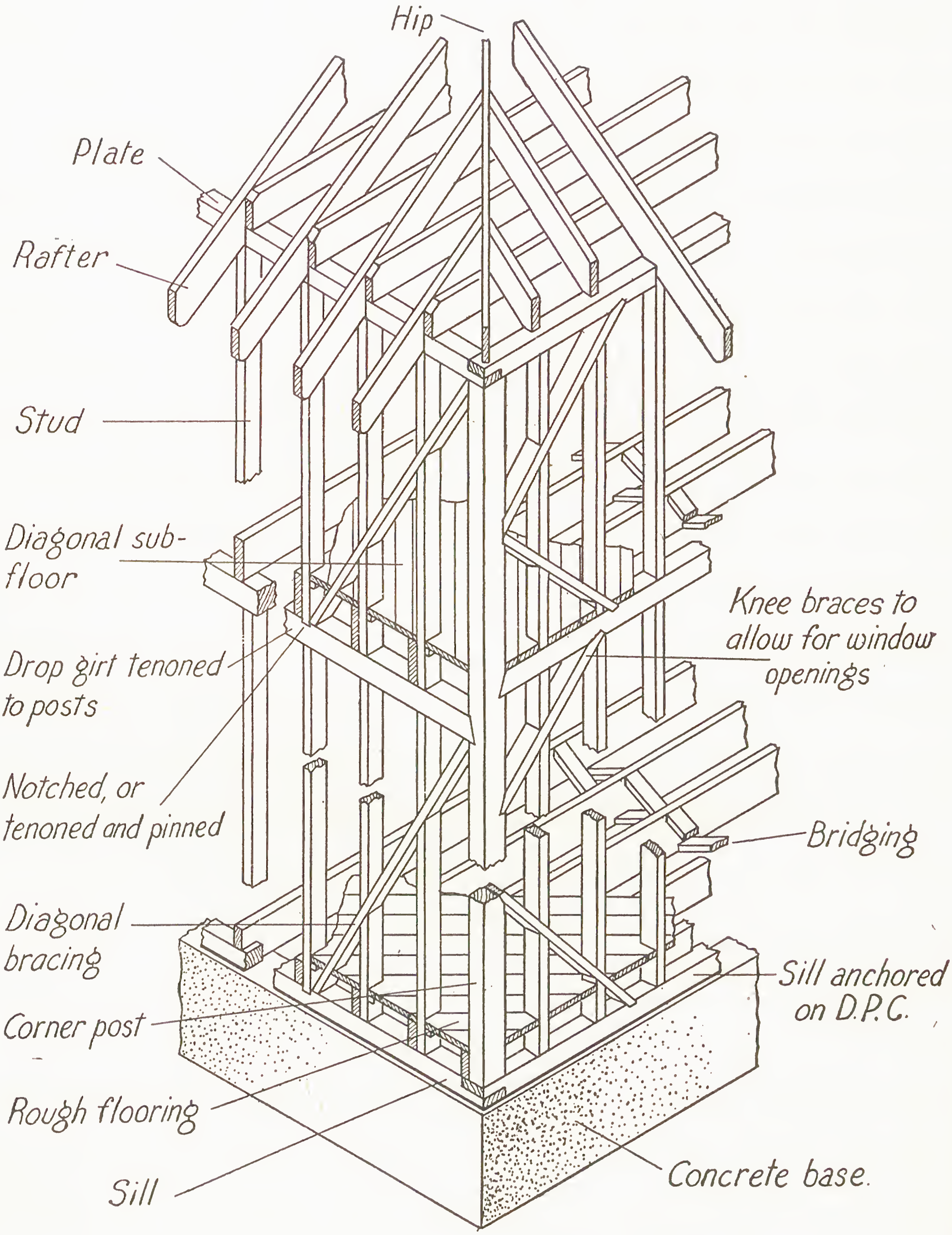


Fig. 77.—Braced frame construction. (*Courtesy Timber Development Association.*)

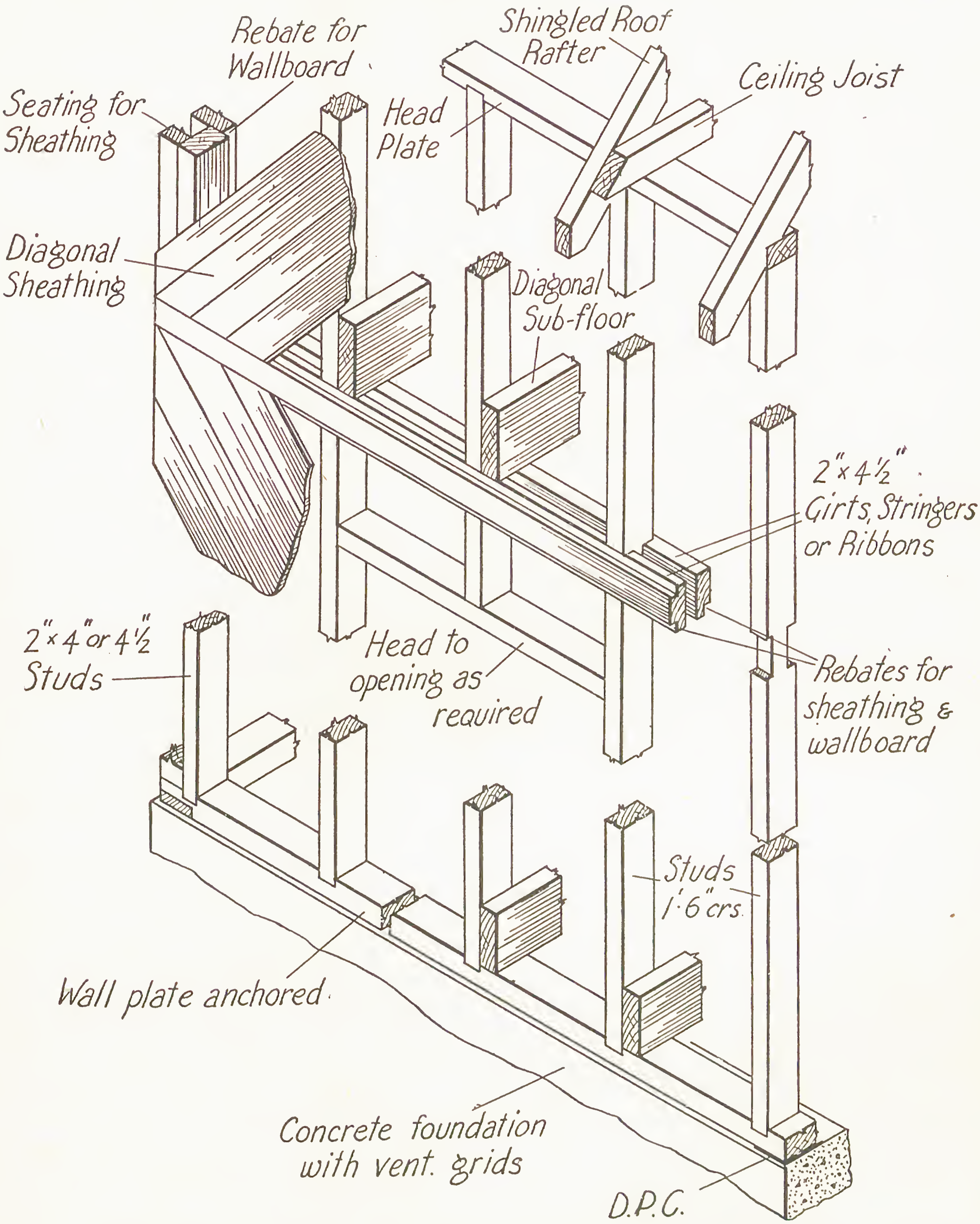


Fig. 78.—Balloon frame construction. The diagonal sheathing braces the frame. Outer cladding is nailed to this. (*Courtesy Timber Development Association.*)

provided that detail drawings are prepared so that exact dimensions can be taken from them. Sectional construction is illustrated in Fig. 81.

Cladding.—The exterior walls of timber-framed buildings can be clad with weather boards, plywood, asbestos-cement, expanded metal, and rendering, or any suitable material.

Weather boarding consists of two main types: horizontal and vertical. The horizontal types are illustrated in Fig. 82. Vertical cladding consists of plain-edged or grooved and tongued-edged boards with vertical cover strips nailed over the joints.

Feather-edge boards are used for cheap temporary sheds. They are liable to admit rain and dry wind if the slightest warping occurs.

Rebated feather-edge boards are much better and are suitable for the best timber buildings, especially if under-boarding is used.

The rebated and chamfered section and the tongued, grooved, and chamfered section have flat faces of uniform thickness and are the best types.

Under-boarding should be used for all but the lightest buildings. If nailed to the studs diagonally at 45 degrees, they brace the frame, and they also greatly increase the thermal insulation of the walls. A waterproof membrane either of building paper or bituminous felt should be tacked to the under-boarding before the outer boarding is nailed on. The walls will then be water- and wind-tight.

In sectional timber buildings the problem of making the joints between sections perfectly weather-tight is rather difficult. Cover strips and mastic may be used, as shown in Fig. 81. This illustration also shows how the construction is sectionalised for bolting together.

It is advisable to use wrought timber planed to exact sectional dimensions. This will make the construction easier than would be the case using sawn timber.

The framework is erected on a low foundation wall, and as this wall is a necessity, in any event, it would seem an economic waste not to put the space it encloses to some practical use. In America and Sweden, where the timber-framed building is much more general than in England, the most economical method of dealing with this foundation wall is to form with it a semi-basement, half in and half out of the ground. Whilst this practice may give the buildings a somewhat stilted appearance, it does provide, at little additional cost, if any, a spacious basement, invaluable for the accommodation of the central-heating plant, a coal storage, and home laundry. The very great advantage of having the laundry work done at home—and this without interference with the proper work of the kitchen and scullery—is highly appreciated; and the additional comfort gained by installing some form of central heating is becoming much more generally recognised in modern buildings in this country. Whereas central heating in houses used to be regarded as a luxury it is now felt to be a necessary incentive to the purchaser.

Considered economically, this semi-basement, half in and half out the ground, need not necessitate any excavation additional to that which is

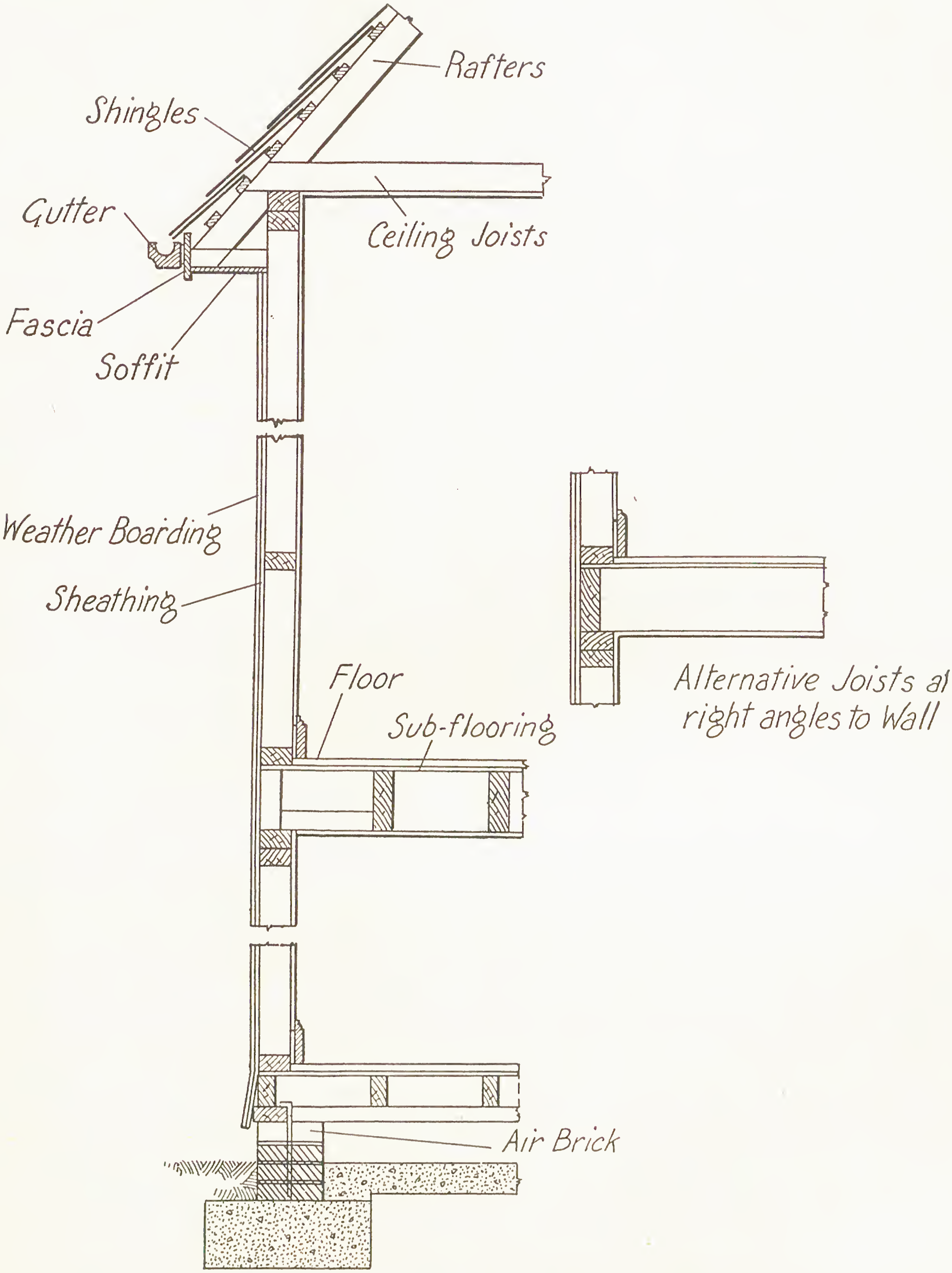


Fig. 79.—Platform frame construction. The floors form platforms on which wall frames are erected. (*Courtesy Timber Development Association.*)

already required to remove all vegetable soil and to lay in the surface concrete usual under rafter and boarded floors in most ordinary conditions. The raising of ground-floor 3 feet or so above the ground may tend towards an unfamiliar stilted appearance, which, however, may be easily counteracted by the external treatment of the design. But if it is altogether too distasteful to contemplate, the basement may be sunk in the ground, not, of course, for use as inhabited rooms, kitchens, etc., as in the past, but solely for the purposes mentioned above ; or if it is preferred that there should be no basement at all, the situation becomes the same as that obtaining in the forms of construction to which we are more accustomed in this country.

A foundation wall of brick, masonry, or concrete is in any case required. This should be at least 9 inches thick, and extend to the height of the plate under the ground-floor joists. The plate or sill should be 6 × 8 inches, or in lighter work 4 × 6 inches, and be halved and pinned at the angles. It should be secured to the foundation wall by means of $\frac{3}{8}$-inch bolts fitted on their upper ends with screws and nuts and bent into a hook at its lower end. On these sills the floor joists are laid and nailed thereto, and where the flooring is double, the lower floor boards are then laid. Corner posts consisting of either two 4 × 2-inch studs or a single 4 × 4-inch, or in still stronger construction of 6 × 4-inch, are then raised at the angles, being temporarily braced with boards nailed diagonally from the plate to the corner post.

The alternative method is to notch out half of the floor joists for jointing them to the sill and to erect the corner posts and intermediate upright studs with their feet against the joists and nailed thereto through the sides. The intermediate studs, 4 × 4 inches, are erected by nailing a board temporarily from corner post to corner post to stay the studs, which in a two-storey building are cut in single lengths for the two storeys. The studs at door and window openings are double and nailed together.

Over the tops of these studs and corner posts are laid two 4 × 2-inch timbers spiked together to form a plate. This plate carries the rafters, which are bird's-mouth-notched over it, and the ceiling joists, which are laid on it and diagonally nailed to it through their sides. The ceiling rafters are also nailed horizontally through their sides to the rafters against which they are placed.

The upper floor joists are then laid in, their ends being spiked to the upright studs and rested on a 7 × 1-inch board, housed into a chase cut on the inner face of the studs and nailed thereto. This board is termed the *ribbon*. This, though not required on the walls parallel to the floor joist, is replaced by a floor joist nailed to the studs to act as a stiffener.

The temporary braces are then removed, and permanent 6 × 1-inch boards are let into chases cut in the outer faces of the studs diagonally of a depth necessary to finish flush.

It will be seen, however, that this form of construction necessitates at least two reductions in the thickness of the upright studs, and a

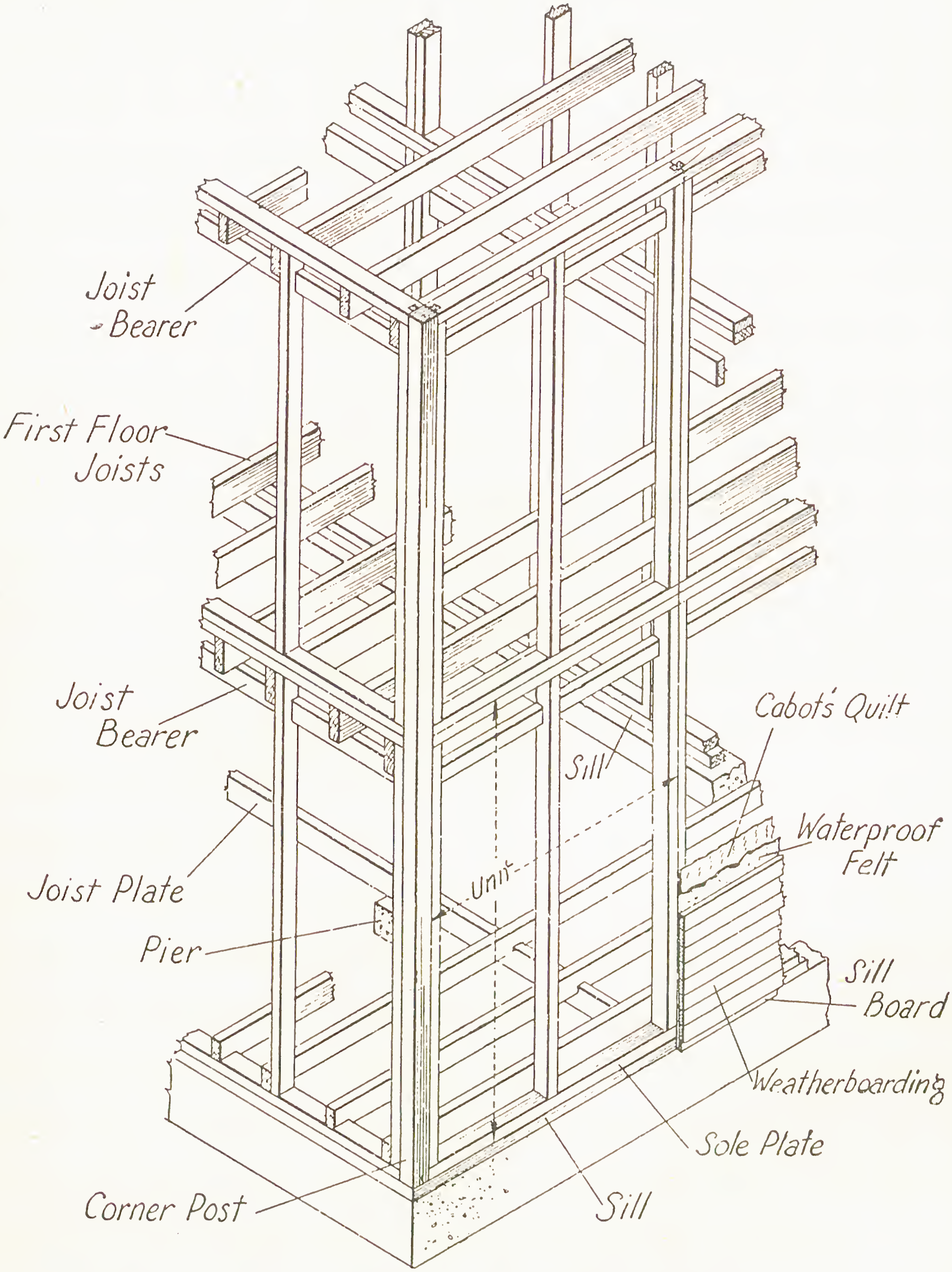


Fig. 80.—Unit frame construction. Partly prefabricated—main skeleton frame is erected on site—workshop-assembled panel frames are then fixed. (*Courtesy Timber Development Association.*)

consequent weakening results; but the method is cheap and quick to erect, and is found to be sufficiently strong for all ordinary requirements. Additional stiffness may be given to the structure by sheathing the outside walls all over with 1-inch boarding nailed to it diagonally.

The practice of running the studs up the height of two stories considerably reduces the amount of work; and at the same time it renders it almost essential, due to the doubling of the studs at openings, that windows in the upper storey should come over those in the storey below.

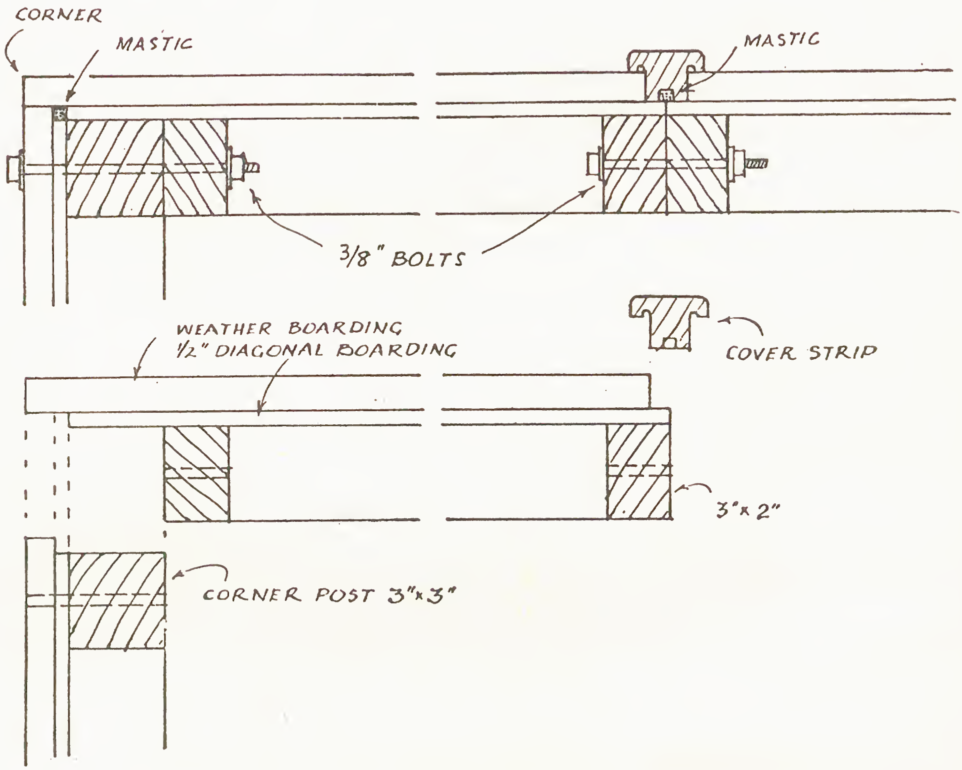


Fig. 81.—Sectional construction for small timber buildings. Sections are bolted together.

However, from the appearance point of view, this is an advantage rather than otherwise.

The Braced Frame is a stronger form of timber-wall construction, and consists of a combination of the former and the methods mainly in jointing practised in mediæval half-timber construction.

The construction of the sills, posts, girts, and braces is similar to that already described, though the dimensions of the timbers may be increased. The main difference consists in the introduction of an 8 × 4-inch horizontal timber to carry the upper floor hoists, and in the fact that the intermediate studs are cut at this point into two lengths—a length to each storey.

The Sills are, as before, laid on the foundation wall, halved and bolted thereto, and may be 8 × 6 inches or 6 × 6 inches, and the corner posts may be single, as before, or framed up of two posts, having their longer dimensions one each in the length of each wall forming the right angle, *i.e.* the posts are framed with the longest dimensions of their sections at right angles to one another. These corner posts, whatever form in plan, must extend from sill to plate at the level of the ceiling joists to the upper rooms in one length: and in the better-class work they should be tenoned to the sill. A corner brace is cut in with a dovetailed halving to afford lateral support to the corner posts run from the sill to a point about two-thirds of the height of the corner post. The joint at the foot of the brace to the sill is formed with a splayed tenon having splayed shoulders and a square abutment at the bottom at right angles to the line of the brace.

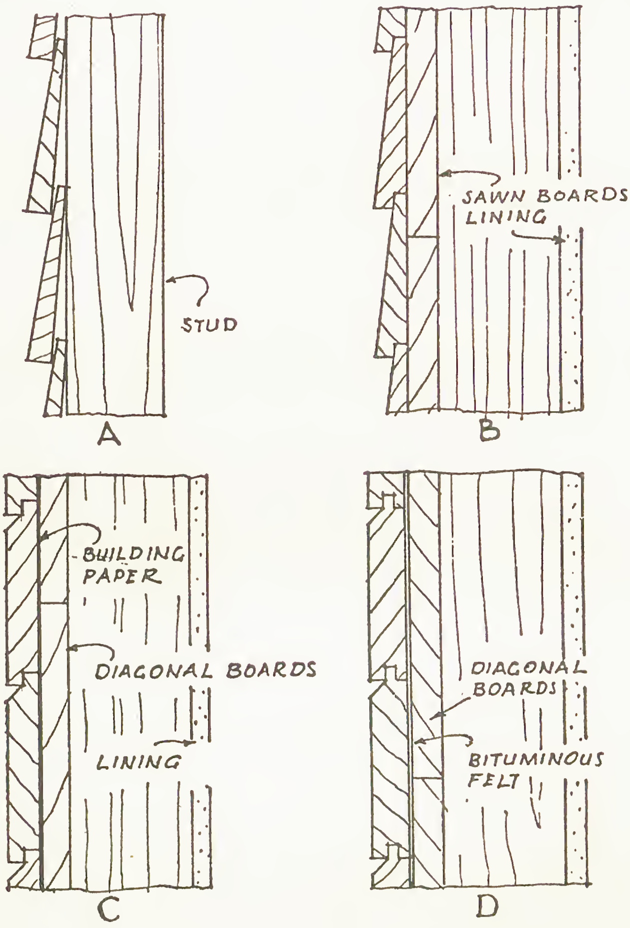


Fig. 82.—Horizontal weather-boarding timber-framed structures.

A. Feather-edged boards for light buildings.
B. Rebated feather-edged boards on sawn boards.
C. Rebated and chamfered shiplap boards.
D. Tongued, grooved, and chamfered boards.

Too much importance cannot be given to the bolting of the sill to the foundation wall, and to give this an equal bearing on the wall it should be bedded in cement mortar. Instances have been known where, during construction, owing to the omission of these *Anchor Bolts*, the walls and roof having been sheathed, the whole framework was lifted from the site and deposited on another. The sill should be set back one inch from the outside face of the foundation wall, and in the best workmanship they are mortised and tenoned at the angles.

The studs are mortised to the sill at their bottom ends and butted, cut square, under the girt.

The junction between the girt and the post is formed with a tenon having a splayed shoulder to afford a support throughout the whole thickness of the girt on the post. A hardwood pin, $\frac{7}{8}$ inch, secures the tenon.

The top floor or ceiling joists are rested on a 7×1-inch *Ledger* let into the inner face of the studs and corner posts and nailed.

A Raised Girt is run along the sides parallel to the floor joists, at the same level, and tenoned and pinned into each post at its end.

In Laying Out the positions of all doors and windows are marked on the sill, and against these marks the edge of the studding is raised. Otherwise it is customary to indicate the centre line of all timbers, as working to these tends towards greater accuracy than working to the outsides of timbers which may not be cut in equal dimensions.

With regard to the cutting for jointing any of these timbers used in frame construction, due regard should be given to the fact that the strength of a timber submitted to any strain is that of its weakest part. Consequently, when sills are mortised for studs and posts, they are weakened by the operation, and their dimensions should be increased to counteract this. This is of particular importance where the sills are not carried by solid masonry, but are run from pier to pier over openings below. It then becomes a question to be decided as to whether the benefit gained from cutting the sill away to form a mortise and the necessary thickening of the sill to make up for this is made worth while by the actual strength given to the joint by the mortise. It might appear that this weakening and tenoning at the feet of the studs is unnecessary in any event, because any outward pressure at the feet of the studs is not likely to be too great to be resisted by the nails and diagonal sheeting, and any sideway motion in the direction of the length of the plate should be sufficiently counteracted by the diagonal bracing and diagonal sheeting. Further, *Nogging Pieces*, as used in partitions, may be inserted in horizontal lines between the studs, which would afford a far greater resistance to sideway movement and at the same time greatly add to the rigidity of the whole frame. The mortising the feet of the studs, though customary, would appear to be an unnecessary practice, especially as, being cut every 14 inches apart, the total amount of timber removed from a sill in its total length is considerable and quite out of proportion with the rule given by Professor Rankine for the cutting away of timbers in jointing, as follows :

Rules for Cutting Timber in Jointing.—(1) To cut the joints and arrange the fastenings so that the pieces of timber which they connect are weakened as little as possible.

(2) To place each abutting surface in a joint as nearly as possible vertical to the pressure which it has to transmit.

(3) To proportion the area of each surface to the pressure which it has to bear, so that the timber may be safe against injury under the heaviest

FIG. 83.—TRADITIONAL TIMBERED BUILDING WITH STRAIGHT-BRACED CORNERS.

FIG. 84.—PAIR OF COTTAGES. UPPER FLOOR TIMBER-FRAMED AND WEATHER-BOARDED. ROOF COVERED WITH CEDAR SHINGLES.

Swan, Norman & Clay, Architects. (Courtesy of W. H. Colt (London), Ltd.)

load which occurs in practice, and to form and fit every pair of such surfaces accurately, in order to distribute the stress uniformly.

(4) To proportion the fastenings so that they may be of equal strength with the pieces they connect.

(5) To place the fastenings in each piece of timber so that there shall be sufficient resistance to the giving way of the joint by the fastenings shearing or crushing their way through the timber.

The Studding used in buildings of greater size than houses, such as schools, requires to be at least 6 × 2 inches when the corner posts do not require to be increased in section proportionately. However, as it is essential that good hold should be secured for the sheeting on to the corner posts, they should always be at least 2 inches wider than the studding. The stiffening effect of this sheeting is considerable, and consequently the work requires just as much care as any other in frame construction, though it is frequently scamped or performed in a slipshod fashion, or the sheeting entirely omitted, which last is a very unwise practice.

Cross Walls.—The cross walls or partitions in frame construction, where they span any considerable distance, should be trussed, and whilst it is customary to space the studding on 14-inch centres, it should be noted that a partition framed of 4 × 2-inch studs spaced 16 inches on centres is much stiffer than one formed of 3 × 2 inches on 12-inch centres, although the second uses up far more cube of timber.

In the light construction the studs of partitions are based on *Sole Pieces*, 4 × 2 inches, laid over the floor boarding, and have 4 × 2-inch heads running over their tops and nailed to the underside of the floor joists. Nogging or bridging, 4 × 2 inches, is cut in between the studs horizontally.

Internal Partitions are carried on beams, 12 × 8 inches, supporting the floor joists, and themselves being supported in their lengths by 12 × 12-inch wood balks or brick piers. But as will be seen, this construction allows of a considerable shrinkage owing to there being a great width of timber crossways between the feet of the studs and the head of the posts or piers; and this shrinkage, always greater than end-to-end shrinkage, will in time, because of considerable settlement in internal partitions, result in cracked plaster work, especially where the support to the outer walls is solid masonry, in which there is practically no shrinkage. Consequently, partitions in upper storeys should have their studs rested on the cap of the lower partition without the thickness of the joist coming between. To make quite sure against this shrinkage and consequent cracking in the plaster, the studs should be rested on a light strut beam, which, being required for stiffness rather than for strength, does not require to be of any great size, and may, in fact, consist of a 4-inch wide plate, ½ inch in thickness, bolted to the underside of the floor joists. The latter is perhaps the most satisfactory method, as any shrinkage in the joist will tend to tighten up the studs rather than to allow

them to drop. Studs running the same way as the joists are rested on a similar plate fixed to cross braces laid in between the joists.

The partitions themselves are constructed in the manner already explained, it being even more necessary in frame construction that they should be trussed than in buildings the outside walls of which are of masonry or brickwork. The reason for this, of course, is that the cross partitions cannot be afforded such support nor such rigidity by framed outer walls as by solid masonry. A trussed partition will serve the additional purpose of supporting the floor above it.

The Caps of framed trussed partitions are two 4 × 2-inch timbers nailed to the top of the upright studs, and the cap should be slightly "crowned" to resist any sagging tendency on settlement. The supports at the ends of the partitions, where they are trussed, are of more importance than when not so formed, for the same reason that in masonry walls additional support, in the form of templates, is given at these points. When the partition is run at right angles to the floor joists the cap is nailed to their under surface.

And when the partition runs parallel with the joists above, they are strapped, as has already been explained in the description of ordinary untrussed partitions ; and the cap is nailed to the underside of the strapping. An alternative to strapping is the insertion of cross braces—short lengths of studding let in between the joists and run at right angles to them. To afford a fixing for the ends of the laths in this form of construction, a flat board is nailed to the cap of the partition, of sufficient width to give at least 1 inch projection at each side beyond the width of the cap.

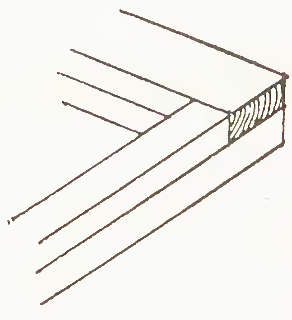


Fig. 85.—Double sill.

The Truss is formed in manners similar to those already described for trussed partitions in masonry buildings, and where there is a doorway required at the centre of the partition, the truss is formed of Queen post. Trussed partitions should not be rested on side walls over openings or if this is unadvoidable, there must be double cross studding framed in the side walls to give additional support to the ends of the trusses, at cap and sill.

The Sill should be 10 × 4 inches and the diagonal braces of the truss at least 4 × 4 inches.

All Openings, whether in ordinary partitions, trussed partitions, or side wall framings, should be trussed, having a head over the opening of two 4 × 2-inch timbers, and splay notched into the uprights forming the sides of the opening.

Junctions of partitions with side framings must be so formed as to afford nailing for the lath ends. This may be given either by framing three studs together in the following manner—two studs are placed in the outer framing about 2 inches apart and a third one is nailed to them

across the space between them, thus leaving 1 inch of each stud projecting at each side of the third stud: or, alternatively, the studs in the outer walls are spaced at the usual distance apart, and the stud to the cross partition has a board 1 inch wider at each side nailed to it to give fixing for the laths.

Sound Transmission.—To prevent the transmission of sound in frame buildings the partitions may be formed in a manner similar to that advised in floor construction for the same purposes. The partition in these circumstances is framed with double studding, the studs being alternated or staggered, and Cabot's quilt or other-sound-deadening material is tacked to the inner sides of the studs.

Pipes and Wires.—All pipes and wires run up interior partitions should be boarded over instead of plastered to afford ready access in case of need.

Brickwork in Frame Construction.—Chimney breasts and stacks are built in brickwork, masonry, or concrete, in frame buildings, as in buildings constructed of ordinary walling. The breasts of the chimneys, however, are not carried up their full-face width for the whole of the height of the rooms in which the fireplaces occur. Considerable brickwork is saved by this means, and the breast may be corbelled out again, if required, for a fireplace in a room over. The breasts are reduced to the flue size as soon as the arching over the fireplace opening and the gathering in of the opening internally permits. In order to maintain the vertical lines of the chimney breast, 4×2-inch studs are framed vertically in at the angles of the breast before it is reduced, and a 4×2-inch plate is rested on the last flush brick course to form a sill for these angle studs, and the intermediate studs are fixed at the ordinary distances apart. Over the tops of these angle and intermediate studs a 4×2-inch head piece is run, nailed to the studs and to the underside of the joists, floor, or ceiling above, as the case may be. The intermediate studs, being in short lengths, do not require to be more than 2×2 inches; and if a sufficient projection is not afforded by the setting back of the brickwork, the sill, 4×2 inches, may be placed on its 2-inch face. It is important to remember that no studs or other woodwork should be placed closer than 3 inches to any chimney flue. Where central-heating flues are required, these also should be built in brickwork, with a fire-clay pipe lining. The faces of the flues may then be battened, though a safer method is to frame around with narrow studding in such a manner that no woodwork comes into actual contact with the flue brickwork.

Wall and Roof Coverings.—The framing of the walls and roofs, as soon as erected, should be sheathed with rough unwrought boarding, which will form a better bracing if it is fixed diagonally, the openings for doors and windows being sawn out after the sheathing is fixed.

The sheathing to the rafters may be either close boarded and battened or laid with a space of 2 inches between each board. A waterproof building

paper should be nailed over the open board and *over* instead of under the battens, as is so often seen.

Outer Coverings for Walls.—It is customary in Canada and U.S.A. to cover this sheathing with either clapboard or shingles, but the bye-laws are in most places in England prohibitive of these coverings.

However, a satisfactorily fire-resistant form of construction is to be obtained by fixing over the rough boarding expanded metal lathing nailed to battens. To this metal lathing a coat of rough-stuff plaster is applied, and finished either with a stucco or roughcast face.

This method of construction, though fixed to woodwork, does in fact form what is practically a thin sheet of reinforced concrete, which is generally accepted as one of the most fire-resistant forms of construction. The slight thickness of the material is no real disadvantage in the matter of resistance to fire, it having been proved that no material yet devised for use in building construction will resist a conflagration, but that the thickest and apparently the strongest suffer the worst destruction.

Nor do walls built of reinforced concrete rely on their thickness for damp prevention, and as frame buildings do not rely on their outer coverings for support, this form of construction would seem to meet all modern requirements, especially if the methods advised for waterproofing cement (see Chapter 6, Vol. II) be employed in additional protection of the roughcast or stucco against damp penetration.

Roofs.—It is also possible to construct the roofs of the same reinforced concrete material, the customary lines of the tiling or other usual material being cut with a trowel and straightedge, or, alternatively, the roof may be framed behind a formwork consisting of feather-edged boarding fixed upside down to give the effect of a coursed roof. For these reinforced concrete roofs rough boarding is nailed to the rafters, waterproof paper and battens being then nailed on, and on to the battens the expanded metal lathing is spread. The cement stucco is then spread by the plasterer in the usual manner and demarked in the manner explained above. Ridges and hips are formed of half-round concrete channels inverted, and the valleys may be either similar channels the other way up or be formed of the roofing materials, described in Chapter 13, Vol. II, with a metal valley formed in the angle underneath.

Eaves, Gutters, and Down Spouts in frame construction are often formed of wood. The gutters consist of either tow boards nailed together to form a triangular trough of a V shape and supported on wood brackets, or they may be a square timber in the upper surface of which a half-round channel is cut.

In districts where the snowfall is likely to be excessive, eaves gutters are boxed square below the line of the roof slope ; the bottom of the box, being carried on wood brackets, is fixed to the studs of the outer walling. The outer side of the box gutter is formed of a narrower board of a width sufficient to allow the roof line to be continued past the box gutter and to

finish at the end of the wood bracket last mentioned. The purpose of this projection and continuation of the roof slope is to assist in carrying sliding snow past the gutter and so prevent blockage.

Wooden down-spouts are formed of two half cylinders hollowed out and rebated at their edges for jointing.

Wooden gutters and down-spouts, however, are not to be recommended, as they offer no very great resistance to frost if they are allowed to become choked.

Eaves Construction.—The construction of the eaves is a more than usually important matter in frame construction, as it is essential that water from rain and more particularly from snow should be shed well away from the wall faces underneath.

In districts where the snowfall is likely to be heavy, as has been explained, a flatter pitch is required to be given to the roof, to prevent the snow from sliding when the thaw sets in. For the same purpose wide gutters and snowguard rails will be required. Alternatively the sliding of the snow may be assisted in order that the roof may be relieved of it as soon as possible. To this end a wide projection is given to the eaves and a very flat gutter, sufficient only to check rainwater, is formed on the roof surface over the eaves projection. This is constructed by running a tilting fillet at a point just beyond the face line of the wall to afford a finish for the roof-covering material ; and lower down the slope of the projecting eaves a 2-inch board or batten is nailed on edge to form the lower margin of the flat gutter. Over these two parallel edgings the leadwork, zinc, or copper forming the gutter lining is laid and tacked. Small wood brackets may be cut in to give additional support to the lower batten.

An alternative method of forming a snowproof gutter is to halve the end of the rafter feet by cutting away its upper half for a distance of 8 inches from the foot and to run boarding along these to form the bottom of the gutter. The lower edge of the gutter is then constructed on top of the boarded bottom in the manner last described. The roof covering is ended above the top of the cut-away halving over a tilting fillet run parallel to the rafter ends.

Asbestos Cement Sheeting in lengths of 4 feet and 6 feet affords another means of effecting this same end, and forms a satisfactory fire-resistant wall covering for use internally and externally. The sheets are butt jointed, and nailed with a special flat-headed nail, and the joint is covered with a special asbestos strip supplied for the purpose. This sheeting can be sawn to any size required, and any openings should be trimmed round with the special strips supplied.

Asbestos cement sheeting is now supplied in several colours, which overcomes an objection to it in its first form, when it was of a dull and uninteresting grey. Gutters and down-pipes are also now to be obtained made of asbestos cement.

A great advantage of this type of roof and wall covering is that beyond

being a preventive against fire, it is also warm in winter and cool in summer, as it is a non-conductor of heat.

Roof Construction in frame buildings is similar to that in ordinary work, as is described in Chapter 4, though possibly the careful preparation of the framing plans already referred to is of greater importance. These should be drawn in conjunction with the framing plans of the floors and outside walls, as the obtaining proper bearings for the heavier roof timbers is a matter of even greater importance in frame construction than in solid work. The bearing of all rafters on wall plates should be at least $2\frac{1}{2}$ inches for 6-inch rafters and 3–4 inches for from 8-inch to 10-inch rafters, and the wall plates on which they rest should be doubled.

In American timber-frame construction the ridge board is often omitted, the rafters being splay cut, and a 1-inch board cut into a triangle is nailed across the splayed joint so formed.

Checking.—It is additionally necessary in forming framework construction, that all the various parts should be erected truly vertical, and this must be assured by constant checking with the plumb lines during erection.

Additional care will also be required in the framing up of the hips. Also, if the plate for the rafter ends is 3 feet above that used to carry the floor joist to the top storey, as is sometimes done to give additional head room in the rooms found in the roof, the ends of the rafters should be tied down by a 6×1-inch board nailed to their sides and to the sides of the floor joists, these boards being erected at an angle not greater than 45° with the floor joists.

Timber Connectors.—In large timber structures metal timber connectors are now used in conjunction with bolts. By distributing the stress they enable timbers of smaller section to be used than would be possible with bolts only. Timber connectors are further described in Chapter 4 of this volume.

CHAPTER 7

JOINERY: WORKSHOP EQUIPMENT, JOINTS, AND PANELLING

JOINERY covers such woodwork as the building of staircases, the making and fitting of doors and windows, and all the interior woodwork finishes and fittings in a building. For such purposes it will be obvious that, as a finer workmanship and finish than for carpentry is required, fine-grained woods free from noticeable defects are required and warping and shrinkage must be carefully controlled. Also, as any shifting after the wood is in position, especially if painted, is objectionable, it is necessary to give careful consideration to the way of the grain, and the matter of jointing becomes one of even greater importance than in carpentry.

Consequently, before describing the construction of doors, windows, and the various fitments, as jointing, grain, and seasoning play so prominent a part in the craft of joinery, it is advisable to give first a general account of the joints used, classifying them under their uses and the strains which they are designed to resist, with some notes on the methods of workmanship and the varieties of wood employed in the various processes and for the different purposes.

Timbers Used.—The timbers used mainly for the following purposes are:—

General Interior Joinery.—American red and yellow pine; oak; pitch-pine; mahogany; Kauri pine.
Staircases.—Treads.—Oak; teak.
Panelling.—American yellow pine; Christiania white deals; mahogany; cedar; basswood; maple; oak; sycamore; whitewood.
Floors.—Russian deal; white fir; pitch-pine; teak; maple.
Window Sills.—Oak and mahogany.
Furniture.—Yew; pitch-pine; beech; chestnut; elm (chair seats); lime; walnut; mahogany.
Doors—Imported.—Oregon pine.
Drawer Linings.—Cedar.
Cabinet Walling.—Indian mahogany; plane; satin walnut; satinwood.
Veneer.—Ebony; maple; rosewood (pianos); Indian walnut.
Handrails.—Oak; mahogany.
Decoration.—Maple; lime (carving).
Plywood.—Poplar; birch, etc.
Draining Boards.—Teak.

Many Empire woods are now used, and plywood and laminated board are often used where solid wood was formerly.

WORKSHOP

Though a great deal of the joinery is worked in modern times by machinery, all fixing on the job is still done by hand, and in much work hand-made joinery is still required. Many people value highly the evidence of craftsmanship to be seen only in hand-made work, and regret its lack due to machines necessitated by the economic considerations of time and cost. In the shop the machine has practically superseded hand work.

The workshop should be well lit, and though top lighting is often used, this should be in the nature of north lights, to avoid overheating, the loss of output from which is often considerable. To aid in this there should be louvre ventilation in the walls. In addition to north lighting there should, if possible, be windows along each long side of the shop. For artificial lighting electricity should be used wherever it is obtainable; and over each bench there should be a movable drop light.

In starting a workshop, on the part of the general builder, it is not necessary to lay out any considerable sum for equipment, as so much of the joinery can be purchased ready made.

Good Benches are a necessity, and of these the single type is preferred, though for large work, on which more than one man is required, a large bench will be necessary, and this should, if possible, be situated in the centre of the shop.

A Single Bench is 10 feet long by 1 foot 10 inches wide by 2 feet 9 inches high. The top, 11 × 3 inches, is of deal. The rails, 3 × 3 inches, should be mortised into the legs 5 × 3 inches, and the rails should be braced by struts, bird's-mouthed on to a rail under the centre of the top. Half the top should form a well at a lower level, which is bounded by a front board fixed with its height vertical; and on the other side there should be a drawer hung to the underside of the top with hardwood runners.

The Vice is an essential feature of the carpenter's bench, and for saving time one with some form of slip ratchet, known as an *Instantaneous Grip Vice*, is most suitable.

On the top there must be a *Bench Stop*, consisting of two pieces of hardwood in the form of a pair of fox wedges in a hole about 2 × 2 inches.

The Sawing Stool is another simple though essential requisite, of which there should be several in the shop. The top of this trestle should be about 2 feet 3 inches from the ground and out of $4\frac{1}{2}$ × 3-inch stuff, 2 feet 6 inches long, with a V cut in one end horizontally. The legs must be well splayed out of 3 × $2\frac{1}{2}$-inch stuff, shoulder on to and housed into the top, and across the tops of the legs under the ends of the top there must be flat boards cleated on to act as stiffeners.

Cramps.—Of these there are a variety to be obtained, including a heavy cramp and a sash cramp in metal, wooden cramp frames for wedging up sashes; a *Universal Cramp* for mitred joints, and the *Flooring Cramp* for making tight side joints in boarded floorings.

Cleats are tools used for applying pressure at one side of wide boards glued together along their edges, and are to be obtained in metal and wood. A *Box Cleat* is a frame formed in a square, and is used for fox-wedge jointing.

Other Tools and Bench Accessories include: the *Bench Knife*, which is used to grip boards held at the other end by the bench stop; the *Bench Hook*, for steadying material when shouldering tenons; the *Mitre Box*, for sawing mitres, which is a wooden three-sided trough with angle kerfs cut in the sides to guide the saw to the desired angle; the *Mitre Block*, a solid appliance in wood for mitreing pieces too small for the mitre box; *Adjustable Mitreing Machines*, which hold the saw fixing for use at any desired angle, are to be obtained.

A Shooting Board consists of two differing widths of flat boards jointed together flat-wise, the smaller on top of the larger. A stop is let into the upper board across the grain and the board is used for "shooting" the ends of boards for butt jointing by laying the board to be planed on the upper board with its edge projecting just beyond the edge of the upper board, and the plane placed on its side is slid backwards and forwards along the lower board.

Panel Boards are used for planing thin material.

Glue is a most important accessory to the joiner's work. It is supplied either in solid form or as a liquid, which requires no preparation. The solid comes in sheets, which must be broken up and steeped in cold water until it becomes a jelly. It is prepared mainly from the horns and hoofs of animals, which are steeped, washed, boiled, strained, melted, and reboiled and then dried in the flat sheets mentioned. Poor glue is made from bones, and is to be avoided, as it will dissolve in cold water, whereas a good glue should swell in cold water. The best glues are transparent and of an amber colour, having no black or cloudy spots, and they should be hard and without odour when cold.

The Glue Pot into which the broken-up glue is placed for heating must be a double pot, having the outer one filled and kept filled with water, otherwise the glue will burn. It should also have a cover to keep the glue free from dust. Heat until the glue melts—this should be a gradual process of from two to four hours—then add sufficient hot water to make an easily workable glue. After use always add boiling water to thin out. It is best if the quantity required can be gauged to make a fresh batch each time. The strength of glue can be increased by the addition of a little powdered chalk.—*Tredgold.*

Water-resistant glues are marketed under various proprietary names.

These are used in aircraft construction and are strong and durable but will soften if continually immersed in water.

"*Marine Glue.*—One part of indiarubber is dissolved under gentle heat in 12 parts of mineral naphtha or coal tar. When melted, 20 parts of powdered shellac are added, and the mixture is poured on metal plates to cool. It is applied by a brush in a melted state, and is specially suitable for all work exposed to wet or moisture."—*Rivington.*

Liquid Glue is more suitable for outdoor use than ordinary glue, as it is not so readily affected by damp.

JOINTS

The jointing in joinery is work requiring considerable skill and fineness of workmanship, as it appears to a large extent on the surface and it has to bear inspection from close at hand. Also, as it is essential that the pieces of wood used should be small, there is a greater frequency in the employment of joints than would otherwise be required. Further, though glue is used, as has been explained, the joints when cut should be of such a fit that they will hold before any glue is used. Joints for external work should be painted over with white lead, ground in linseed oil.

PLANES

The success of a joint depends largely upon the operation of planing the surfaces of the boards to be jointed before any cutting is performed. For this purpose the sawn timber first requires "roughing down" with a large plane known as the ***Jack Plane,*** which is made in sizes from 14 inches to 17 inches and has a blade from $1\frac{3}{4}$ inches to $2\frac{1}{2}$ inches. The setting and sharpening of the blade is a very important matter, which practice alone can teach, it being noted here that upon the amount of the blade which is allowed to project from the plane will depend the thickness of the shaving, the usual projection being about $\frac{1}{32}$ inch. This is termed the set of the blade, whilst the set of the back-iron is the distance which it is set behind the blade. The surface through which the blade projects is called the sole of the plane, and it is essential that this should be held level when planing. If the blade is projected too far it will jump and not slide smoothly over the surface, cutting long shavings as it should; and for planing the rough sawn face a greater projection is required than when planing fine. The parts of the *Jack Plane* are: the body of beech; the blade; the cap or back-iron; the wooden wedge for holding the blade set; the handle at the rear end; the button on the top of the front end; the body or stock, and the mouth, *i.e.* the slot through which the blade projects and up which the shavings pass through to the space above, which is called the escapement.

The Trying Plane and the ***Smoothing Plane,*** the first long, and the second short, are for finishing, and require the blade more finely set. Smoothing planes are also made of steel.

The first thing to learn in planing is to plane level, and the earliest attempts generally result in planing more off the farther end of the board than off the near end. This is due to the exertion of more pressure on the button with the left hand at the end of the stroke than at the beginning. The way to overcome this is to exert an equal pressure with both hands at the beginning of the stroke and to lighten that on the button at the end of the stroke. In the same way, as it is easier to plane a board at its edges than in the middle, the beginner will find that at first he planes more off the sides than at the centre, so that he should test the surface frequently during the operation with a straightedge laid across the surface of the board.

When planing the edge of a board across the end grain, to prevent the fibres splitting at the end, chisel off the angle.

To plane the edges square, use the trying plane and the shooting board, holding the board tightly against the shoulder stop.

The Pitch is the angle at which the blade is set in the stock of the plane. For all-round work this should be 45°, and for hard and long-fibred wood, 50°.

Sharpening the blade is also an important matter and one requiring practice, as the finished blade must be square but without corners; if much rounded, the surface of any wood planed with it will be ridged. Though the angle at which the plane is ground is only 25°, the sharpening angle should be about 35°. The blade is sharpened on an oilstone by rubbing it backwards and forwards, held at the required angle until the edge has a thin turn up on it. Then the blade is reversed and held flat down on the stone and worked backwards and forwards angularly a few times.

Mouldings and Grooves are mostly cut by machinery at the present time, but planes are to be obtained for these operations, and are mostly used by cabinet makers.

CHISELS

The chisel is the next tool most in use by the joiner, and of this there are various forms, including the ordinary chisel with a rectangular flat blade; the gauge; the heavy mortising chisel; the paring gauge, and the long bevelled-edge paring chisel, each of which has its proper uses.

The grinding angle is 25° and the sharpening angle 35°. In sharpening the right hand holds the chisel by the wooden handle and the fingers of the left hand press lightly on the blade. After the edge is finished turn over as with the plane, and remove the wire edge by drawing the chisel over the oilstone from the farthest towards the nearest end in a sweeping motion.

It is particularly important that the oilstone should have a flat surface, and this can be assured by frequently rubbing the stone on a large flat stone with a little sand and water.

Oilstones should be oiled with neat's-foot oil, or a mixture of sweet oil and paraffin.

In chiselling the tool is generally held so that the square edge is towards the cutting line and the bevelled or ground edge away from it. Especially is this so when cutting across the grain, and the action given to the chisel, besides being that of a cut downwards or across the grain, must also have a slightly rotary action in the direction of the fibres. The tool is grasped by the fingers and thumb of the right hand and guided by the thumb of the left hand touching the blade near the point; meanwhile, pressure is put on the end of the wooden handle by means of the right shoulder or the chest of the worker. The usual mistake made by the beginner is to pare off too much at each action; the shaving should be very fine, the finer the better. It is essential to remember that, when cutting to a line as for a mortise, which is performed with the mallet instead of the shoulder, the square side of the chisel should be held about $\frac{1}{16}$ inch from the cutting line, as the tendency of the bevelled edge is to force the chisel towards the line. If, therefore, the cut is started *on* the line, the result will be a larger cut than was intended. This is the main cause of a badly fitting joint—and, in consequence, it is well that the beginner should convince himself at the outset that whilst he can always cut more wood away, he cannot put it back after it is once cut. In other words, a too-tight joint can always be pared away, but a too-loose joint is spoiled, as there must be no wedges for ordinary jointing in joinery.

When paring the edge of a board across the grain horizontally, the corner away from the worker should be cut off at a slight angle in the same way—only less so, as was described for planing.

When it is desired to chisel with the grain, as in cutting a chamfer, remembering that the bevelled edge tends to force the chisel towards the cutting line, it is advisable to turn the chisel over and to use it reversed, held at such an angle that the bevel is parallel with the cutting line.

Cutting a Mortise.—The operation is generally started with the brace and bit after the cutting lines have been marked on, the paring is continued with the chisel and mallet and finally the cut cleaned up by paring with the hands and shoulder as first advised. When boring with the brace and bit bore only halfway through from each side, as this prevents splitting.

To cut a mortise without the brace and bit, cut downwards first in a vertical direction, with the chisel held vertically not quite up to the cutting line. Then with the bevelled edge held parallel with the surface to be cut, pare out about $\frac{1}{4}$ inch of the surface in an angular direction to meet the bottom of the first vertical cut. So continue until two sinkings sloping away from the centre towards both cutting lines have been cut halfway through—then turn over and repeat the operatious from the other sides. The central portion is then cut away with the chisel held vertical, and remember—*once again* (this point cannot be too often mentioned)—pare *almost* up to the cutting line, but not quite, as there

is the tenon which is to fit into this mortise to be cut yet and any cutting away too much in forming that will make a loose joint. You can always cut more out of a mortise, but you cannot stick wood back on to a tenon, unless all your tenons are going to be fox-wedged ·

Tenoning.—The operation of cutting a tenon is mainly a sawing job and the less paring to be done to a tenon with the chisel the better, as the rough surface left by the saw teeth gives a stronger fit to the joint. Also a

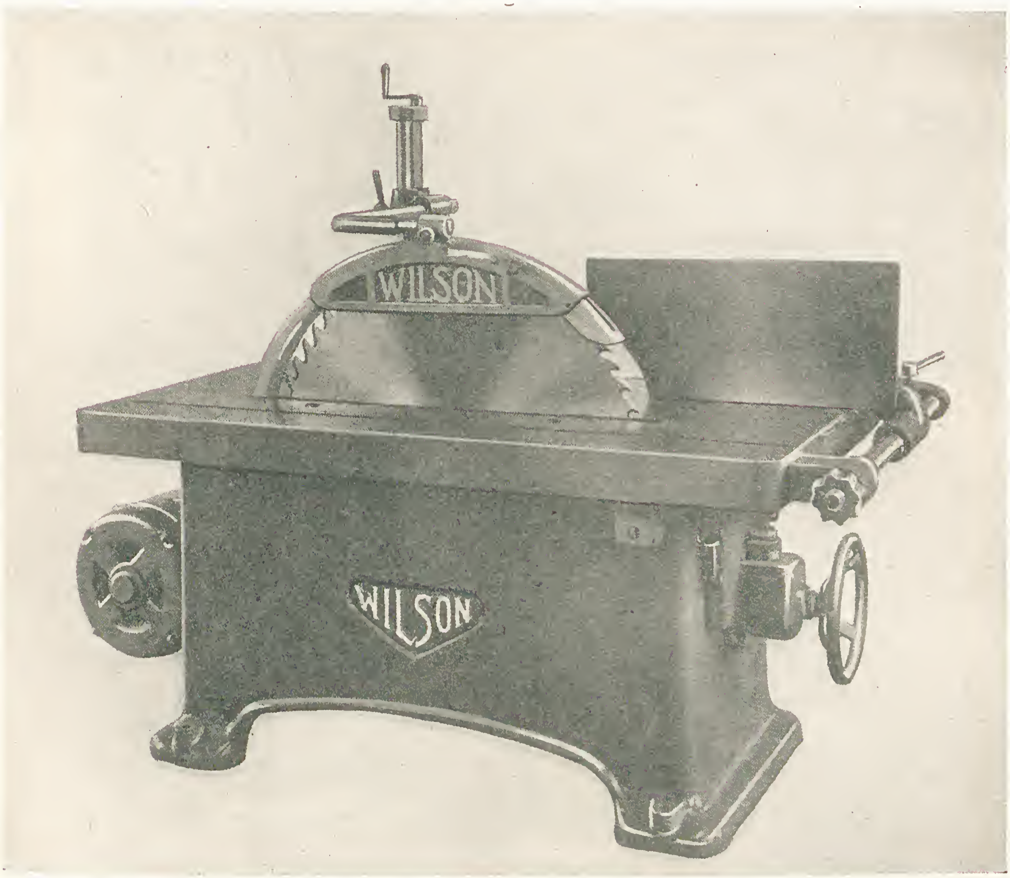


Fig. 86.—Motorised circular saw bench made in four sizes, *i.e.* taking saws up to 26 inches, 32 inches, 36 inches, 42 inches diameter. (*Courtesy of Wilson Bros.* [*Leeds*], *Ltd.*)

tight-fitting tenon-saw cut only means accuracy of workmanship ; whereas the necessity for a lot of trimming up with the chisel means inaccuracy and generally results in a loose joint with unequal shoulders. All kinds of dodges are known for rectifying inaccurately sawn tenons, but by far the easiest method in the long run is to learn to mark the gauge lines correctly and then to saw finely, always working the saw up to, but not *on*, the cutting line. It is not unusual for the beginner to find that the shoulders of his tenon are unequal. This is the result of bad and uneven

planning in the first instance, and inaccurate marking of the cutting line. This shoulder line should be marked with the square *right round the timber* on which the tenon is to be cut, and the line so drawn should finish exactly on the starting-point of the first face marked, or else the timber is not square and the shoulders will be unequal.

Another secret of success in all chiselling operations is to remember that the action of the chisel is a splitting one, caused by the driving of a wedge between the fibres of the wood, and therefore this being such, it is advisable, wherever possible, to cut across the fibres to be split first

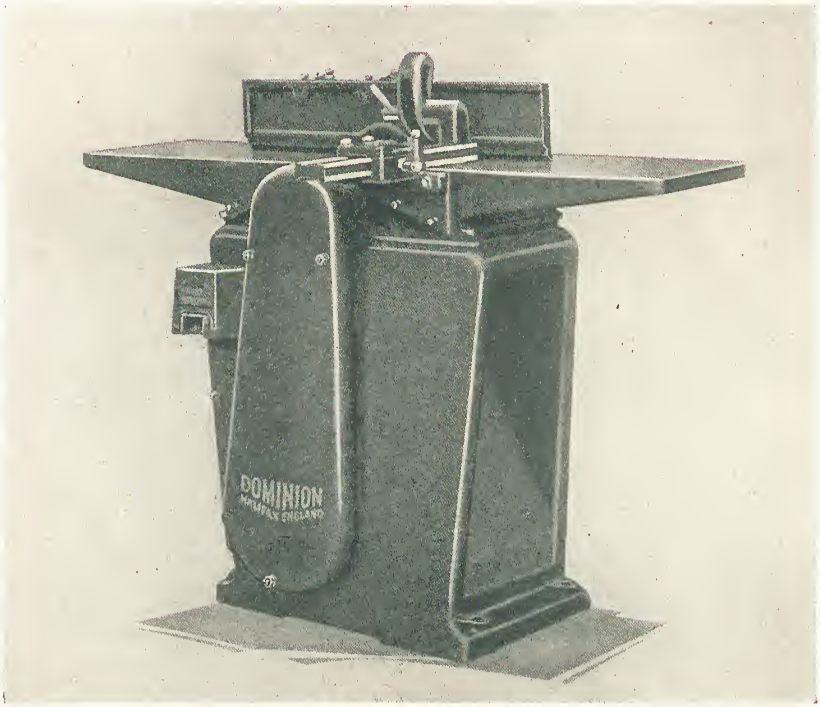


Fig. 87.—Dominion " BP " type surfacing, jointing, and moulding machine.

so that the fibres beyond the cutting line will not be affected by this splitting action.

In cutting an open mortise, *i.e.* taking out the central third at the end of a timber, the saw cuts are first made from the end of the timber to the shoulder line. It is important that these cuts should be accurate and finish square on the shoulder line *on both sides*. When the saw cuts have been made, which, by the way, should be done on the side of the line on which the wood is to be cut away and *not* actually on the line, the cutting away of the central third is sometimes done by working with the chisel towards the end of the timber, starting by paring off the corner and so working down on both sides till the shoulder line is reached. However,

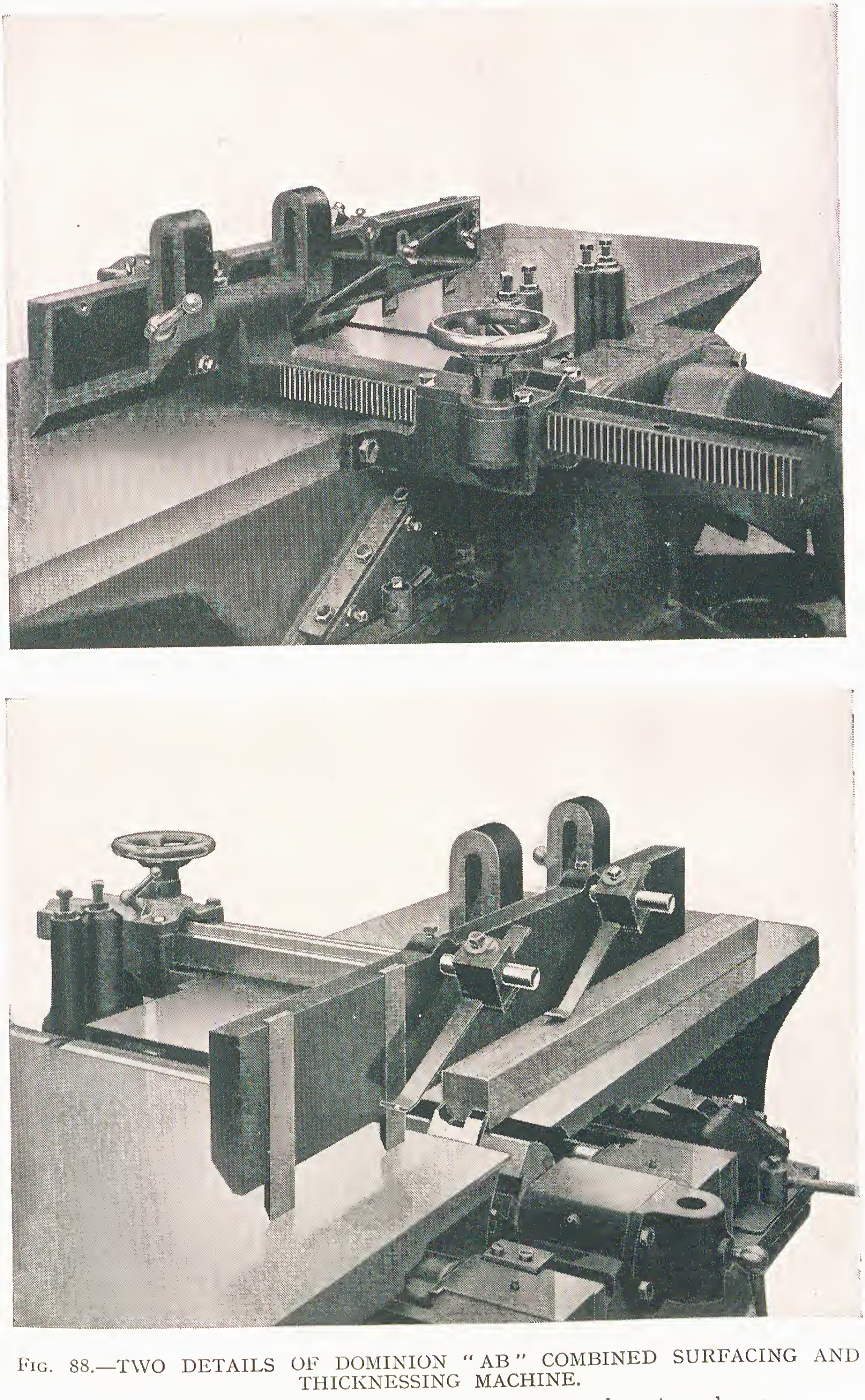


Fig. 88.—TWO DETAILS OF DOMINION "AB" COMBINED SURFACING AND THICKNESSING MACHINE.

(Top) The fence. Front plate can be canted to any angle up to 45 degrees.
(Bottom) The machine arranged for moulding.

a better way is to drive the chisel in about $\frac{1}{4}$ inch vertically with the mallet, with its square edge just within the shoulder line, and then to pare away the central third, working towards the vertical cut. So continue until the centre of the timber is reached, then turn over and repeat the operations until the triangular tongue left of the central third comes away. The vertical interior faces of the mortise should then not require much, if any, further paring with the chisel.

THE SAW

Accuracy of sawing goes so far towards good workmanship in making the joints required in joinery that some understanding of how the saw works when properly sharpened, looked after, and used is necessary.

The first thing to do with a saw on handling one for the first time is not to start sawing at once, but to make a close examination of it. There is a danger of taking for granted such common tools, that one has grown accustomed to seeing for so long, that one never stops to think out the why or wherefore of them. Ask yourself, for instance, why the teeth of a saw cut through the fibres of the wood, and you will be amongst the fortunate ones if the only answer that presents itself to your mind is, "because it always has done," which is not an answer at all. Why, also, is the handle fixed in line with the top edge of the saw blade and not in line with the bottom edge, as this edge, having the teeth, certainly does the work and consequently the latter would seem a more reasonable position for the handle. It will also seem that there are an unnecessary number of rivets through the handle. Why so? If all the saws used by a joiner be examined, it will be found that the teeth of each are of a different shape; and if this examination be made from the end it will be found that the teeth spread out alternately to each side and more on some saws than others.

The proper understanding of all such points will tend towards the proper use of the saw, with the resulting improvement of the user's craftsmanship.

Whilst a saw known as the ***Hand Saw*** may be used for general purposes, it is usual for the joiner to have one saw for cutting with the grain, called the ***Rip Saw,*** and another, called the ***Cross-cut Saw,*** for cutting across the grain. The reason for this is to be seen in the teeth. If the teeth of the *Rip Saw* be examined closely they will be found to consist of a sloping side and a vertical side, the vertical side being actually at right angles to the line along the points of the teeth; and if measured along the points it will be found that these are from $4\frac{1}{2}$ to 5 teeth to the inch.

On the other hand, the teeth of the *Cross-cut Saw* have both sides at an angle, with 6 teeth to the inch, or for use on very hard woods, as many as 8 teeth to the inch; whilst for very fine cabinet work the number of the teeth-points to the inch will be as many as 12.

The handle is actually set centrally and at right angles to a line drawn from the point of the last tooth to the centre of the handle end of the blade;

and the part of the handle which is gripped with the fingers and the palm of the hand is set at right angles to this line. This gives the line of the most direct and consequently effective action of the force applied in sawing. This form of applying force in sawing may convey a wrong idea. So long as the saw is properly sharpened and *set*, and held at right angles in the vertical direction to the plane of the board being sawn, and with the teeth forming an angle of not less than 45° with the line to be sawn down, the main necessity beyond giving sufficient force to push the saw down and to pull it up again is to let the saw do its own cutting, except possibly just before the end of the downward stroke when a sort of kick can be given. It is important also to saw regularly and with a leisurely motion rather than to attempt to hurry the job with quick strokes. Such hurried motion defeats its own end, as will be readily understood if the actual happenings of the process are considered.

In fact, what does actually happen when a saw is pushed downwards through the fibres of a piece of wood is that the sharpened face of the teeth pass between the fibres on each side of a central ridge, this ridge becoming powdered, and passing into the spaces between the teeth known as the *Gullets*. Also if a rip saw is properly set it will be found possible to pass a needle lengthwise along the teeth in the space formed by bending the teeth right and left alternatively. Now, it will be recognised that this powdered fibre, *i.e.* sawdust, requires time to collect and to pass out of the cut made by the saw, *i.e.* the kerf, and consequently any too rapid action of the passage of the teeth up and down will not permit of a sufficient allowance of time for the teeth to become cleared of sawdust, with the natural result that the saw becomes clogged and the actual cutting operation delayed. Therefore the operation must be in the nature of a steady swing with a slight pause when the saw is at the bottom of its stroke. It is most important that the saw be held vertically to the face to be cut; that is to say, if a steel square be placed on the face of the board with its other edge against the side of the saw, the saw should touch the upright edge of the square and show no light between. Also, to give too flat a slope to the line of the teeth is to defeat the purpose for which the teeth were originally cut at the angle that they were, which is the angle that has been found to be most effective in separating the fibres. Consequently, hold the saw with the line of the teeth forming an angle of about 45° or more, even up to 60°, but rarely, if ever, less. In starting the cut, or kerf, place the left hand at the side of the end of the line to be cut along so that the saw rests lightly against the knuckle of the thumb, or if more convenient, extend the thumb, being careful, of course, that the contact is made against the side of the saw blade and above the teeth. Then draw the saw backwards several times, exerting no further pressure than that which the weight of the saw exerts, until the kerf for the guidance of the saw is sufficiently deep. Then begin the downward and upward steady swing with the back edge of the saw, the right hand and the right eye in line. The body of the person, though bending up and

down, must not swing sideways, or the saw will be working out of the perpendicular.

Back Hand, or, as it is sometimes called, overhand, sawing in ripping a long board affords a less tiring method. In this the timber is clamped to the bench and the cut started by holding the handle of the saw below the line with the end of the blade above. When the kerf is sufficiently deep the saw is turned round and held with the handle uppermost and the teeth away from the operator, who stands behind the top of the blade and away from the teeth, and holds the handle with both hands, making an angle between the teeth line and the line to be sawn along of 70°.

Sizes and Requisites.—The rip saw is made in the following lengths, 20, 22, 24, 26, and 28 inches, to suit workers of different heights. The cross-cut saw should be 24 inches long, and a bevel should be filed on alternative sides of alternative teeth. The handles of both should be beech and riveted so firmly that there is no possibility of working loose, as any looseness will interfere with the freedom of the swing. The handle and the blade must be in perfect alignment and the steel of the best temper, so that it will not buckle or break. The blade must also taper in section from the teeth to the back edge. These matters can be left to the maker, so that all that has to be done is to buy from a well-known firm in the first place.

The Tenon Saw.—Whereas the two former saws are as much the tools of the carpenter as the joiner, the *Tenon Saw* is more particularly the saw most used by the joiner than any other. It is used mainly for cutting tenons as its name implies, and for halving, mitreing, and dovetailing; though for the last a specially thin tenon saw is used, sometimes known as a *Dovetail Saw*.

The tenon saw is rectangular, with no diminishing towards the end of the blade, and it has a brass stiffening fitted on to its back edge.

The proper way to hold the tenon saw is horizontally, *i.e.* parallel with the surface to be sawn, except when making such angular cuts as the sawing of dovetails, and even for these it will be found to give better results if the saw is held horizontal and the wood fixed in the vice at the required angle.

Other Types of Saw used by the joiner include: the *Keyhole Saw*, which has a narrow blade for inserting in holes such as that already described, bored in a fixed floor board which it is desired to remove. These saws may be obtained with several blades of varying widths to fit one handle.

A joiner will also have a *Bow Saw*, though this is more used in cabinet making than in joinery upon the job. It is useful for cutting shaped timbers, such as pew ends and curved ends to book cases; and it consists of a thin blade about 12 inches long fitted into a frame having a centre cross rail and a twisted wire or cord at the other side of the centre rail from the saw blade. At the ends of the frame in line with the blade are

two turned handles which are held in operating. The blade is very much thinner at the back than at the teeth, to enable the saw cut to be curved more easily. Care must be taken not to press the two handles together in sawing, or the blade will buckle and snap. It is better to hold only one handle, though if the other is lightly guided, this results in greater accuracy.

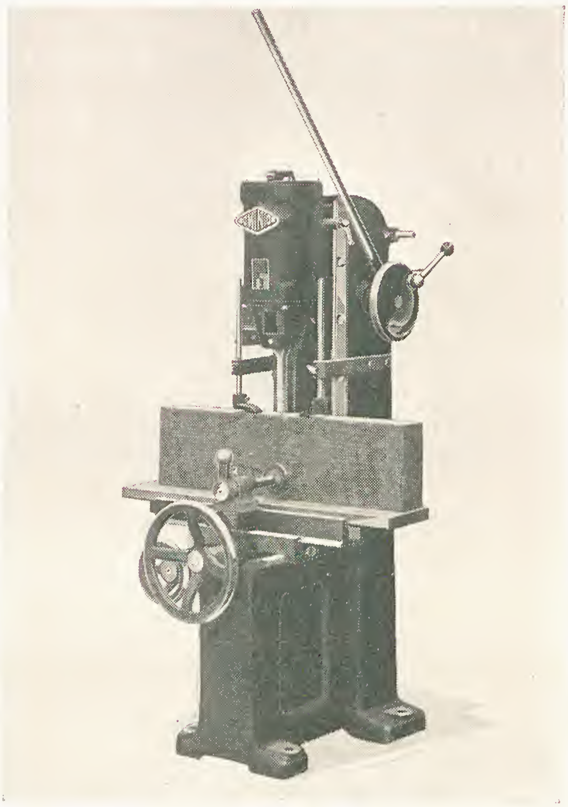


Fig. 89.—Dominion " BM " hollow chisel mortiser and borer.

Setting and Sharpening a Saw.—Setting a saw is a job best left to a specialist than attempted by a beginner, though every joiner should be able to sharpen and set his own saws. Half the pleasure and most of the success in craftsmanship consist in having tools rightly cared for and in the best possible condition.

Setting is the operation of bending alternate teeth to right and left. The bend should start not farther than halfway down the tooth, and it is done with special pliers known as a *Plier Saw Set.*

Sharpening the Rip Saw is performed by filing each alternate tooth at an angle with a double-ended saw file, the file being held at right angles to the saw blade. Then reverse the saw in the vice and file the remaining alternate teeth at the same angle. The cross-cut, tenon, and dovetail saws are filed at an angle to the blade of the saw to give the sharper edges required in cutting across the fibres.

THE BRACE AND BIT

The brace and bit consists of a handle so bent into a three-sided square that the operator is enabled to revolve it with his right hand whilst holding the top either with his left hand or against his shoulder or chest. The main point in using this tool successfully is to make sure that the top is vertically over the bit and kept there during the operation. In boring sideways, or horizontally, the brace must be held at right angles to the surface to be bored as before, and it must not be wobbled at the head. A variety of different-shaped bits are supplied to fit into one brace, and

in the best tools the head is mounted on ball-bearings, which prevent friction. The ratchet-type brace is useful in confined situations.

Though primarily a tool for boring holes, the brace and bit is also a great time-saver for such work as has been described in cutting away the wood in making a mortise, when the main portion of the wood that is required to be removed is bored out by the brace and bit, leaving little more than the paring to be done with the chisel.

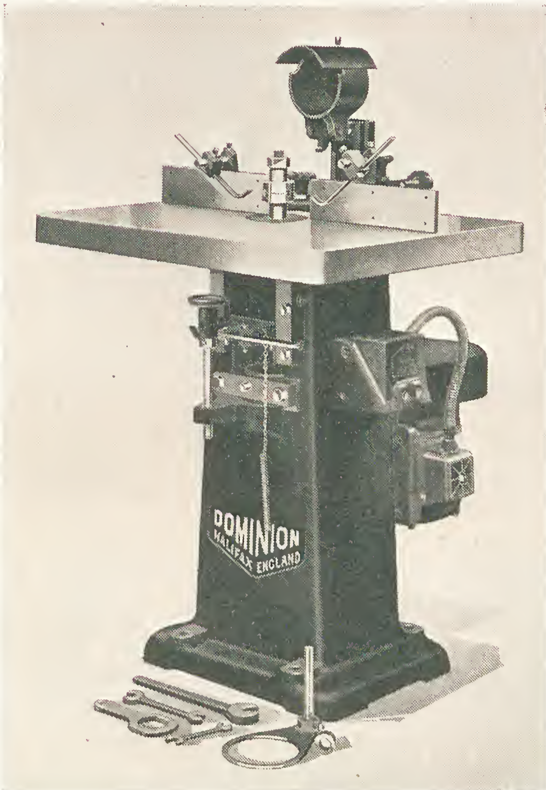


Fig. 90.—Dominion "BL" spindle moulder for motor or belt drive.

WOODWORKING MACHINERY

Most operations in joinery are now done by machinery, resulting in much quicker and greater output of work and saving in cost.

In a modern machine shop each machine is driven by its own electric motor. The older system of driving all or most of the machines from one large motor with an elaborate shaft, pulley, and belting transmission system is wasteful of power, and a breakdown in the motor or main transmission system brings the whole workshop to a standstill. With individual motors less power is wasted in overcoming friction, there is less danger to the machine operators, the layout is more flexible, and machines can be moved without much trouble if it is found desirable to revise the layout. The individual motors used range from 1 to 15 h.p. in the average workshop.

Saws.—The conversion of large timber into small material is done on a heavy circular saw, which may be up to 72 inches diameter, or on a heavy band saw.

In preparing timber for joinery, a good workshop may have three circular saws of various sizes from 26 inches upwards. A saw-bench with a cutting depth of 12 inches is useful for resawing material to produce boards and scantlings.

A circular saw-bench with a cutting depth of 7 inches may be used for several purposes, including ripping, ploughing, and grooving. With a

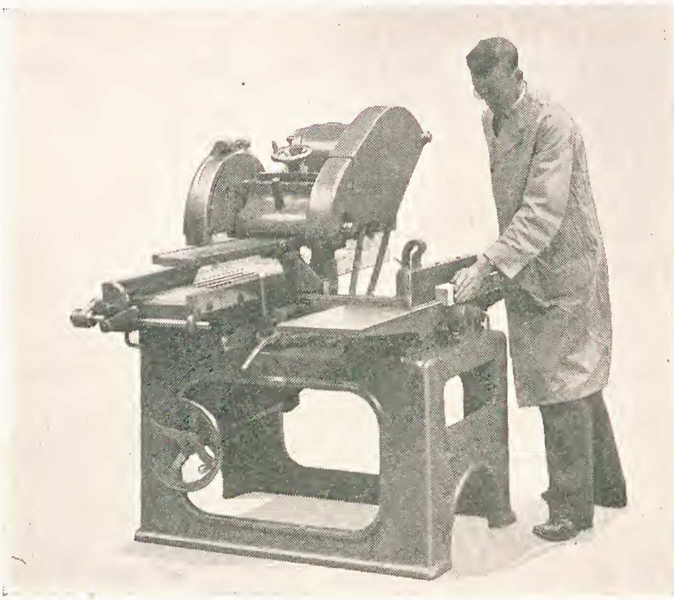


Fig. 91.—Rebating.

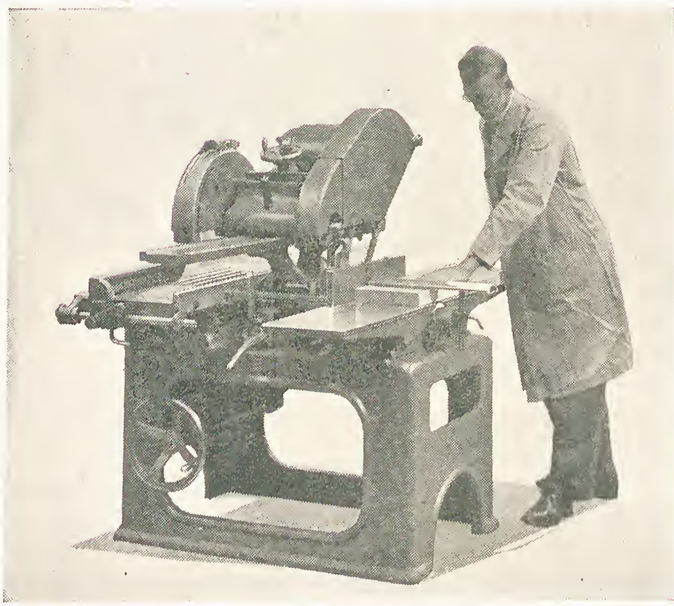


Fig. 92.—Surfacing.

Some operations with "Elliot" woodworker.

(Courtesy of Dominion Machinery Co., Ltd.)

canting, rise and fall table adjustable to exact dimensions the circular saw can be used for rebating, ploughing, and mitreing, and material may be cut to any angle.

Band saws are used for small and shaped work, including curved brackets, handrail wreaths, and circular work.

Planers.—There are various types, each of which has a special purpose.

The overhand planer or surfacer is used for truing-up. The panel planer, or thicknesser, is a heavier machine which can take several pieces of material at a time. It is also used for planing large material, such as wide panels.

The surfacer and thicknesser is a combination planer which is useful in a small workshop but it is better to use separate machines for the two operations.

The surfacer can be adapted for moulding and rebating by fitting special cutter blocks.

Mortisers.—Cutting mortise holes by machine is obviously much quicker than the

laborious hand method. Hand-operated mortising machines are made for occasional use but the power-operated type is used in the average workshop.

The hollow chisel mortiser has a revolving auger which extracts the core and the tool leaves a clean hole.

The chain mortiser has toothed cutters on the chain which cut the hole. The hollow chisel type is usually preferred as it has a wider range of use. Mortisers can be used for other operations, such as trenching and housing.

Tenoners.—These machines reduce the thickness of the material on both sides in one operation.

Spindle Moulders.—On this machine moulding is done by a vertical revolving spindle to which suitable cutters are attached. They are used chiefly for the production in large quantity of architraves, skirtings, picture rails, and panel mouldings.

The recessing machine is a special type of spindle moulder

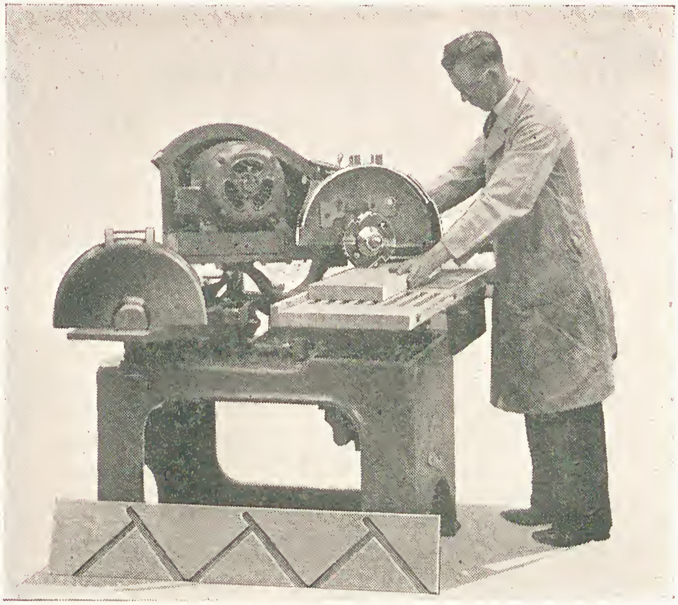


Fig. 93.—Housing stair strings.

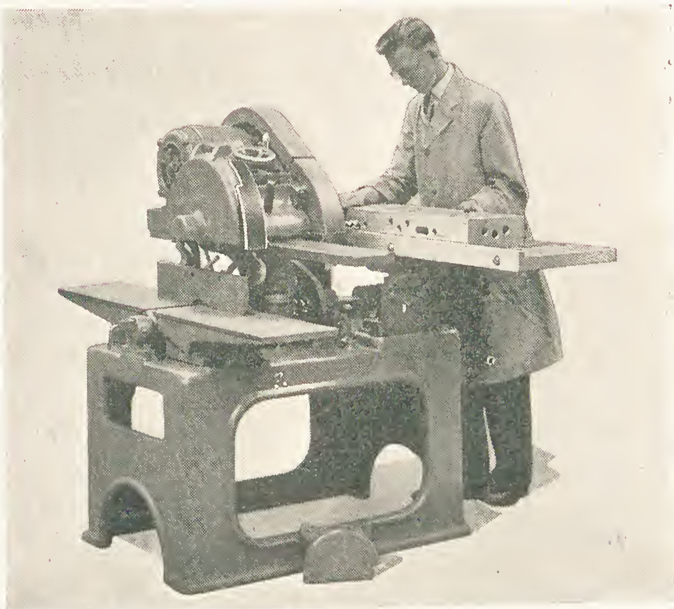


Fig. 94.—Boring.

Some operations with "Elliot" woodworker.

(Courtesy of Dominion Machinery Co., Ltd.)

which is very adaptable for such work as housing stair strings and general recessing.

Universal Machines.—Universal or combination woodworking machines are self-contained joinery mills which can perform any operation, including circular-saw work, planing, boring, mortising, thicknessing, moulding, and tenoning. They are useful both in the small and large joinery shop. In the former they will do what all the separate machines described in the foregoing will do, and in the latter they enable the capacity of the workshop to be varied to suit the work on hand.

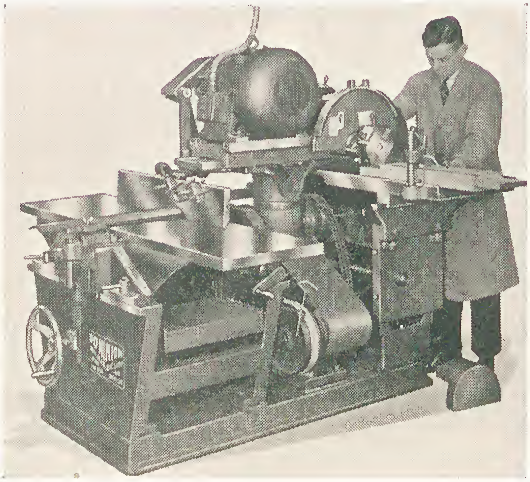


Fig. 95.—Tenoning with super "Elliot" woodworker.
(*Courtesy of Dominion Machinery Co., Ltd.*)

Portable Machines. — Portable circular saw-benches are made for power operation by petrol engines or electric motors which can be connected to the mains. For work on the site these machines save much time and reduce costs.

Sanders.—These machines are used for imparting a very smooth finish to joinery. The output is much greater than is possible by hand methods. The belt sander consists of an endless belt moving at speed and pressed against the surface of the wood. It is used for general finishing.

The disc sander is suitable for small work and the bobbin sander for shaped work. The drum sander is useful for finishing boards and not only imparts a smooth finish but can be used to bring boards to exact thicknesses.

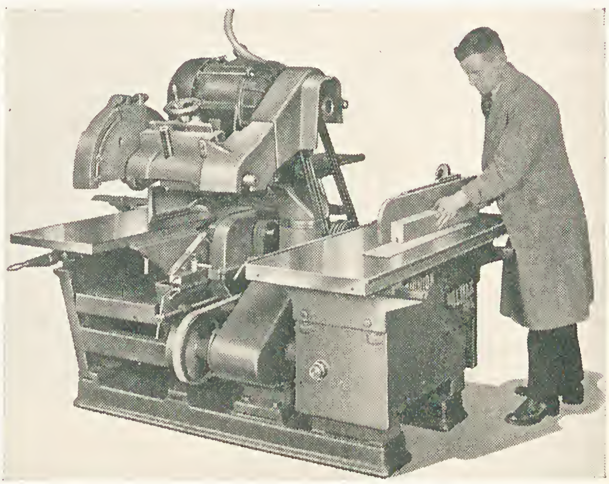


Fig. 96.—Ploughing with super "Elliot" woodworker.
(*Courtesy of Dominion Machinery Co., Ltd.*)

ELECTRIC TOOLS

Portable electric tools are made which greatly reduce the physical effort required from the operator. The

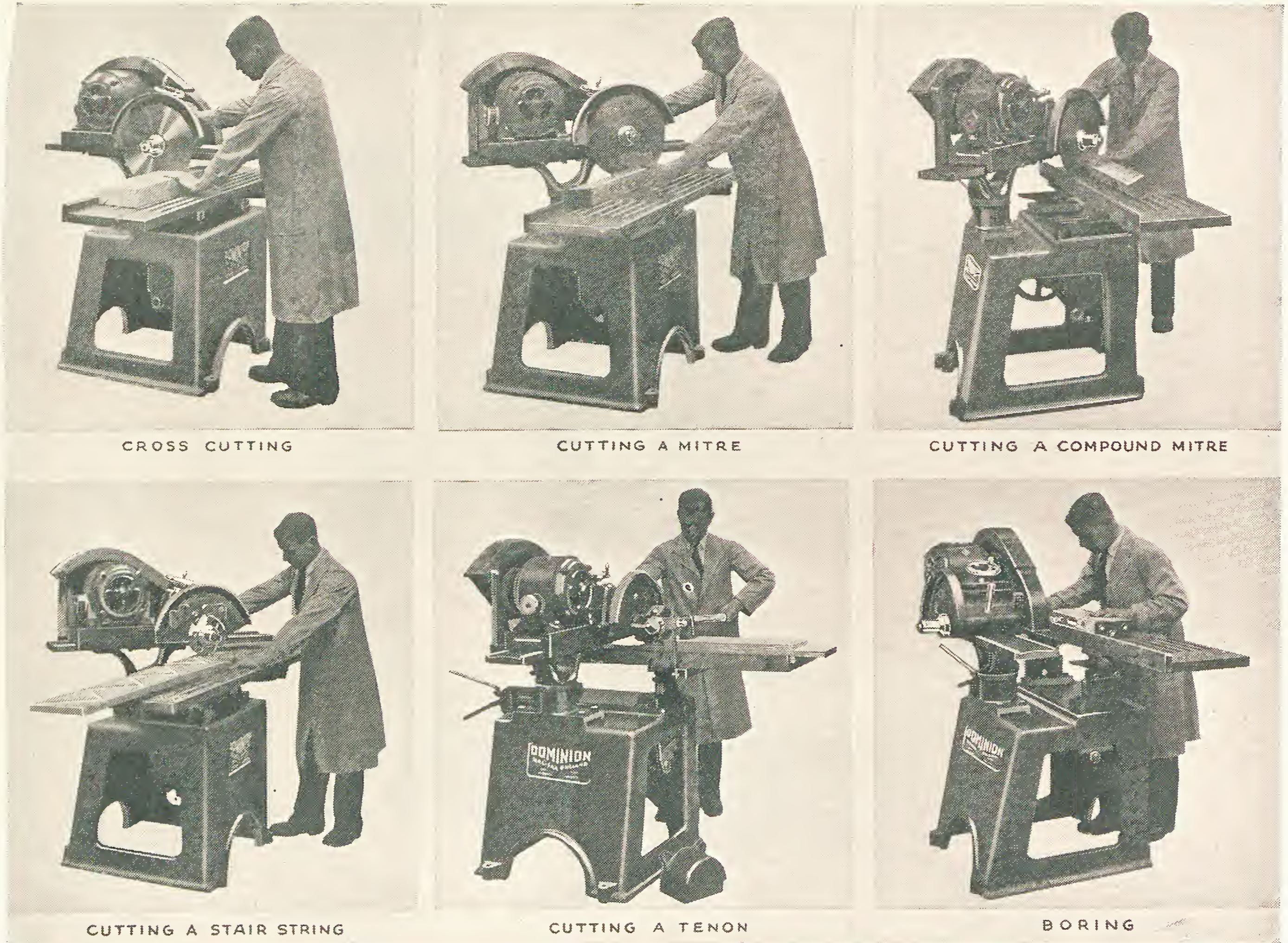


Fig. 97.—Cross cutting and trenching machine. (*Courtesy of Dominion Machinery Co., Ltd.*)

electric drill is the most familiar example. A range of these tools is made so that drilling of any kind can be done, and with a "Holesaw" attachment holes up to 4 inches diameter can be quickly cut.

The portable electric saw will do all that the handsaw can do but with greater speed and much less effort. It is really a small circular saw mill. A fence can be attached to facilitate sawing to a line.

Portable electric screwdrivers and sanders are also made.

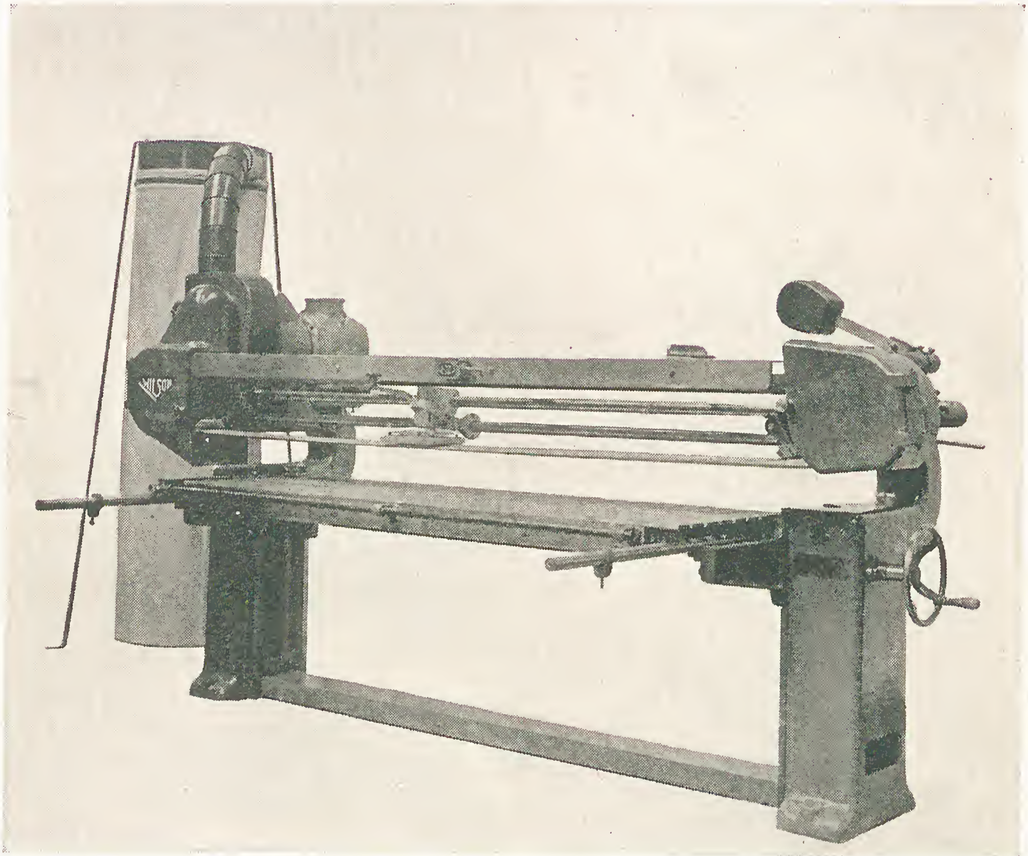


Fig. 98.—Motorised open-end belt sanding machine. (*Courtesy of Wilson Bros.* [*Leeds*], *Ltd.*)

These portable tools can be used in the joinery shop for small work which would normally be done by hand, and they are also very useful on the site provided a temporary connection to the main can be made.

Even the small builder or joiner can afford these tools, and for much of their work they will thus have the benefits in speeding up production and saving labour which are obtained on a larger scale from workshop woodworking machines.

TERMS USED IN JOINTING

The following terms are met with frequently in the description of jointing.

Chamfering is the cutting away an angle or arris of a board. A chamfer is often cut on boards with the same underlying purpose as that of the bead, *i.e.* to conceal a joint. Rebated and V-jointed lining is treated

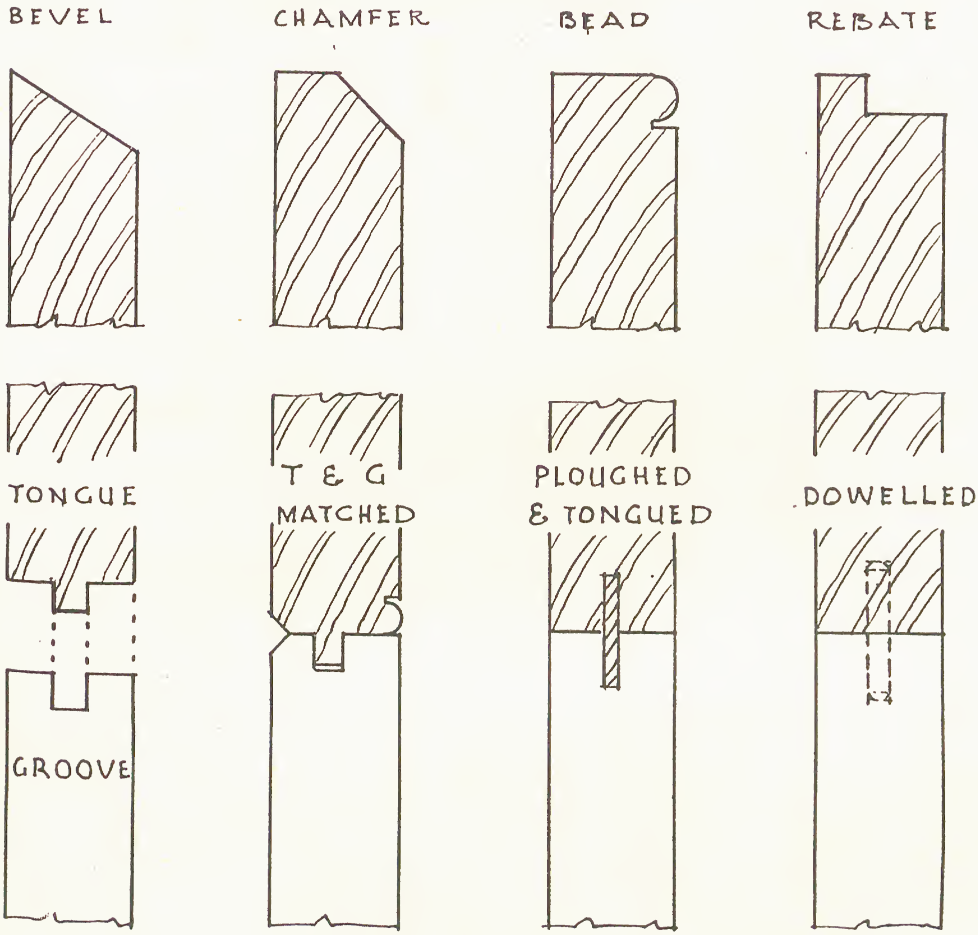


Fig. 99.—Edge finishes and edge joints.

this way, and the battens of built-up doors also for the same purpose. The chamfer is used also for ornamental purposes, as for example, the bottom rail of panelling, the stiles of which may be moulded, is generally chamfered.

When the chamfer is not continued to the end of the board, but ends either in another chamfer, or in a slope, it is called a stop chamfer.

Rebating consists in cutting away an edge of a board or timber a sufficient depth for another board similarly cut to fit, as in the rebated

floor board; or it may be that one timber only is cut away for the reception of the whole of the other, as in the case of a door frame, which is rebated to receive the door when closed.

Shooting is the operation already described of planing the edge of a board true and square as in preparation for the butt joint.

Plough Grooving is the operation of cutting grooves with the grain, and is performed by a specially shaped plane called a *Plough*. Whereas when the groove is cut across the grain, it is called *Trenching* or cross grooving. If the groove is to be stopped, it is cut with the tenon saw and the chisel, but if it is to be run right across the board it is cut by means of a *Grooving Plane*.

Scribing is the cutting of a board to fit against others of irregular shapes or surfaces, such as the bottom of a skirting where it comes over unequal floor boards. Skirtings, when moulded, are also scribed against flat surfaces, forming an angle by cutting one to fit against the other, rather than by cutting mitres on both.

A Mitre is an angle joint found between two boards when both are cut away at an angle as described later.

Blocking is the operation of increasing the strength of an angle joint by means of square glued blocks being inserted in the angle. An example of this is to be seen in the underside of a staircase in the jointing of the treads and risers behind the nosings.

Veneering is the facing up flat or rounded surfaces of one timber with a thin sheet of another, and generally more expensive, timber, as in cabinet doors, etc.

Plywood consists of several thicknesses of veneers glued together with the grain reversed.

Bending of boards is performed by cutting saw kerfs in the back of the wood to be bent, to within $\frac{1}{16}$ inch of the face. Strips cut to fit are glued in the kerfs and the shaped piece screwed to a backing. Thicker wood should be bent in the workshop with the aid of a steam box.

Mortising is the cutting of a rectangular sinking to receive a tenon. A *Stub-mortise* is one which does not pass through the stuff.

Tenoning is the formation of a projection or tongue by reducing the thickness generally, by cutting away the two outer thirds with square shoulders to a size requisite to fit into the mortise cut in the other timber with which it is desired to make a joint. The completed joint is termed a *Mortise and Tenon*.

Shouldering is the operation of cutting the abutting parts of a tenon.

Shoulder Tonguing is the working of $\frac{1}{8}$-inch grooves $\frac{3}{8}$-inch deep in the shoulders which exceed $\frac{1}{2}$-inch in depth.

Dovetailing is the method of joining two boards at right angles when triangular tenons are cut in the edge of one board to fit into similar, but

reversed-shaped, mortises cut in the other board. *Secret Dovetailing* is the method of cutting a dovetail at an angle or mitred so as to conceal the ends of the dovetail tenons.

Fox Wedging is a stub-tenon into which the points of hardwood wedges are inserted, and these, when the joint is driven up, are forced in by the back of the mortise sinking and so causing the tenon to expand. The mortise is cut dovetail to allow for expansion, with the result that a joint is formed which cannot pull apart without tearing the wood fibres.

Draw Boring is a method of tightening a mortise-and-tenon joint by driving a pin known as a *Draw Bore Pin* through a hole bored in the shoulders of the mortise and through the tongue of the tenon, the hole in the tenon being slightly nearer the shoulders than in the mortise, with the result that the joint is drawn tightly together.

Cleaning Off is the production of a finished surface and removing all projections, irregularities, and defects.

Glass or Sand Papering is the rubbing down of the surfaces of joinery on completion with glass paper to remove all plane and other marks, and to reduce the surface to a fine finish. In the workshop, sanding machines are used.

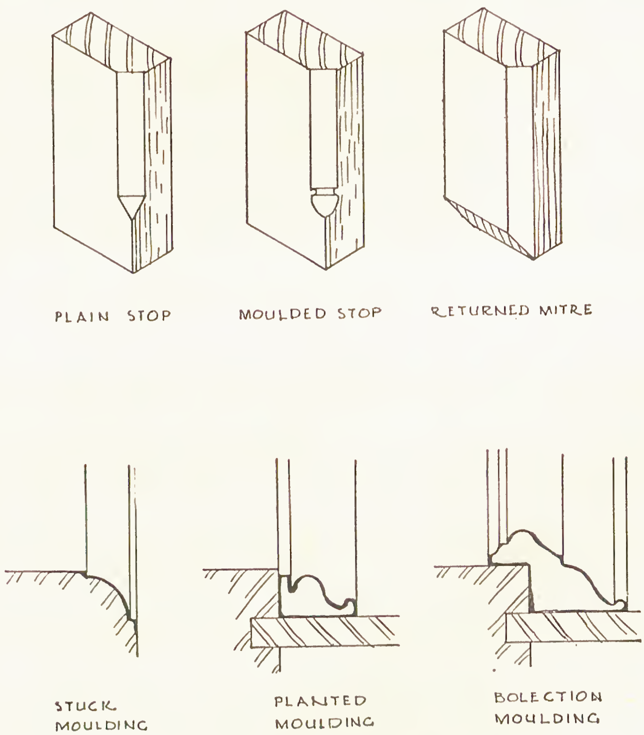


Fig. 100.—(*Top*) Chamfered edges. (*Bottom*) Moulded edges.

TYPES OF JOINTS

The Butted Joint.—The simplest way of joining two boards to make a wider board is to plane their two edges square and level, and then to glue them together. This is called the butted or glued joint.

To plane the edges true it is helpful if both boards be put in the vice together side by side and so planed, testing during the operation with the steel square for squareness and with the straightedge for trueness of level. The boards are then taken out of the vice and tried one over the other, from which operation it will be seen if the surfaces are true. For squareness the straightedge should be held against the sides of the boards in this position, *i.e.* the one on top of the

other, at several points in their length to see if they lie truly against the straightedge, with no light showing between.

The edges are then glued, the glue being allowed to penetrate into the wood, and then, with one board in the vice, the other one is placed in position above it and rubbed slightly backwards and forwards until a close fit is arrived at. The two jointed boards are then leaned against a flat board itself leaned against the wall. Though the joint formed by this method is sufficiently strong for all strain that the boards themselves will support, they may, if desired, be jointed by being cramped. But the success of the joint depends not so much on the pressure applied, whether performed in the first manner described or the second, as on the exactness of their planed edges.

Cut Joints may be classified under the headings which signify the purpose for which they are intended—*i.e. Widening Joints* such as that described above; *Angle Joints*, including *Framing Joints* such as the mortise and tenon used, for instance, in joining door stiles and rails; and *Lengthening Joints*, such as have been already described under carpentry in Chapter 3, Vol. III. Further, the joiner is required to form what are termed *Shutting* and *Hinging Joints*, though these are more in the nature of shaped surfaces which touch rather than joints.

WIDENING JOINTS

The Butt Joint, having no actual fitting surfaces to be cut, but depending on glue to hold it, has been treated of separately, as all the following joints depend for their strength on one cut part of one board fitting into a space cut to receive it in the other.

Tongued Joints.—V-joints and rebated edge joints have all been described in the chapter on carpentry referred to above. Besides being used for floor boards, in joinery these are used mostly with matched linings, boxings, and panelling.

In conjunction with joints there are certain finishes which should be studied first in order that the joints may be the better understood.

A Nosing is the rounded finish given to a board, generally when it projects from the surface of the work, such as is to be seen in the finish given to the portion of a tread on a staircase which projects beyond the riser. This is the basis of the *Bead*.

A Bead is often worked on at the junction line of widening joints, its purpose being to cast a shadow over the joint which in the event of shrinking will conceal the opening. A bead is so "stuck" on one side of matched boarding, and it is equally used with the butt joint and the rebated joints.

A bead is also worked on angle joints, either to hide the opening by the shadow cast when worked on the face of one of the boards which form the angle, or it is worked on the corner formed by the jointed boards

to save the wear that would be likely to damage a sharp arris. It is then known as a *Staff Bead.*

A Quirked Bead is a rounded nosing having an indentation, called a *Quirk*, on one side of it.

A Double-quirked Bead.—The main characteristic of the bead is that it is worked flush with the line outlining the surface of the material on which it is worked; and the double-quirked bead is one which has a quirk on both sides of the bead, the bead itself being worked in the surface of the material. Where a bead is projected beyond the surface it is known as a *Cocked Bead*, and is generally "planted on" or laid in a groove. When the bead rests on a flat strip projecting at both sides it is known as a *Cocked Bead and Fillet.* This is a customary finish given to the shutting joint of cabinet boors, for instance.

When a series of deads is worked on a surface running parallel to one another, this is termed *Reeding.*

A very large bead surmounted by a fillet, as in the base of a column, is known as a *Torus.* This bead frequently forms the top member of a skirting, and is then rather in the nature of a moulding than a bead.

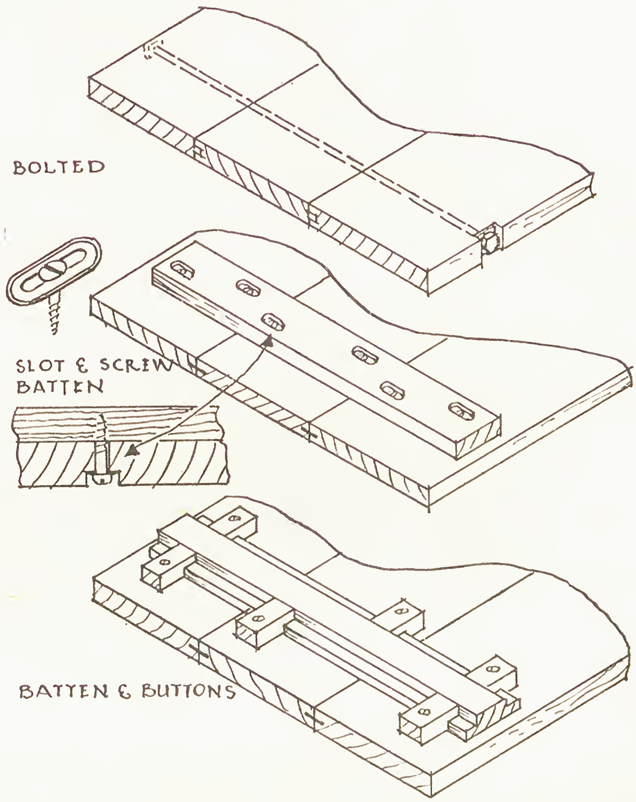


Fig. 101.—Joints for building up wide surfaces and preventing warping.

The Dowelled Joint is an additional strengthening to the butt joint. This strengthening is effected by inserting round pins of hardwood or metal into holes cut in both edges to receive them. The surfaces and the dowels are then glued and the boards cramped as before described. This joint is used at the feet of door posts without glue, and with glue by the cabinet maker as a substitute for the mortise and tenon, when fixing a rail to a stile. When marking the positions for the holes to be bored, for which operation the brace and bit is used, they should be held tightly in the vice, as any inaccuracy in this will cause an ill-fitting joint, which may not fit at all, or the surface of one board will project beyond the

other when stuck together. The dowels will be found to enter the holes bored for them more readily if the edges are cut off their top surfaces.

A joint of a similar nature is that termed the *Secret Screw Joint*, used mostly in fine cabinet work. This consists of a screw left projecting in place of a dowel on one board and a slot into which it is slid on the other. The difficulty lies in cutting the slot, which must have a circular opening at one end into which the screw head may pass. It must also have a continuation of the same width at the side of the screw-hole slot, but this does not appear on the surface. That is to say, the slot is the same width as the screw hole within the wood, but only just wide enough to allow the part of the screw under its head to pass along it. By this means the boards are held together to resist any pulling-apart strain by the screw head fitting against the shoulders inside the slot. The end of the narrow slot must coincide with the upright outer face of the screw, whereas the circular part of the slot must be cut to one side of this. This operation is performed by fixing the board with the circular slot over that with the projecting screw held in the vice and driving the screw head along the narrow slot by tapping the side of the upper board. The boards are then taken apart again and the screw driven about a turn farther into the wood. The upper board is then replaced when both have been glued.

Other Varieties of Widening Joints.—These, as has been mentioned, are mostly the same as used in Carpentry and described in Chapter 3 of Vol. III, but the boards being thinner, the workmanship is more delicate. They are shortly detailed here again with one or two which belong more particularly to joinery.

The Grooved and Tongued Joint has a projecting tongue down the side of one board to fit into a groove cut in the edge of the other board. It is a flooring joint, and when so used it is customary to leave a greater thickness of wood over the tongue than under.

Ploughed and Tongued Joint.—This has a separate tongue of cross-grain-cut hardwood or galvanised iron inserted end on into a groove cut in both boards to be joined.

Slip Feathers are the tongues inserted, and they are termed straight, feather, and cross-grained tongues, according to whichever way of the grain they are cut. As has been said above, cross-grained feathers should be used.

The Dovetail Slip Feather is used in short lengths, mostly in cabinet making. The feather is shaped into a double dovetail to fit into a dovetail groove cut in the edge of each board.

The Rebated and Filleted Joint is a form of slip feather joint used mostly in flooring. The under surface of the edges of the boards are given a shallow rebate, and into this a fillet of hardwood is inserted. The object of the fillet is to close the crack, should the boards shrink.

Splayed, Rebated, and Tongued Joint is another flooring joint having the upper surface of the tongue splayed downwards away from the board on which the tongue is cut.

The Matched Joint is used in wood-sheeted partitions, and may consist either of a V groove or a bead cut on the arrises of the boards and a tongue on one edge and a groove on the other. The tongue and groove is to form the joint and the V or bead to conceal any opening which may arise from shrinkage.

ANGLE JOINTS

The simplest method of jointing boards at right angles as with widening joints is to butt them, but with the difference that in the angle joint the edge of one board is butted against the side of the other. This has the disadvantage of showing the end grain of one board against the side grain of the other, and as there is no real strength in the joint it is generally nailed and in addition it may be glued. This is termed the *Angle Butt Joint.*

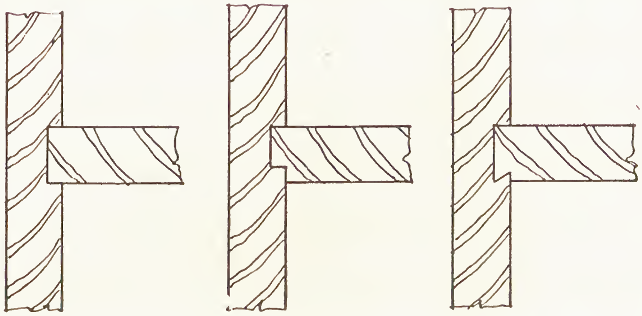


Fig. 102.

An improvement on this is the *Rebated Butt Joint,* in which a rebate the width of the other board is cut on the inner angle of the other board. A still further improvement on the last is the *Grooved and Tongued Angle Joint,* in which a groove is cut on one board at a distance awayfrom the edge of the thickness of the other board on which a tongue is cut to fit into the groove. This has the advantage of concealing the crack should the join open.

Other devices for concealing the opening of the angle butt or angle-rebated butt joints are to work beads on to the arris of the board which shows the end grain or staff beads on to the corner of that board. The latter has the additional advantage that it conceals the end grain.

All the above angle joints are scarcely worthy of the name and are used mostly in cheap work only, or in ground work that does not appear in the finished job.

The Mitre.—What may be termed the angle joint proper is the mitre, or some modification of the mitre. To join boards at angles of 90° the corner of each board is cut off at an angle of 45° and the two cut faces are butted. This is called the *Plain Mitre,* but it has the disadvantage of showing light through the joint if the boards shrink and pull away.

To overcome this defect the following improvements have been devised:

A joint known as the *Mitre and Butt Joint,* which, as its name suggests, is a sort of combination of both mitre and butt, requires the two pieces of wood to be of different thicknesses, so that the mitre on the thicker board does not run all the way through the thickness, but a shoulder is left against which the side of the other board butts.

What is really another form of double butt joint, though called the *Mitre and Rebate Joint,* and suitable for boards of equal thickness, is one consisting of a rebate cut in the mitred ends of both boards so as to form two butting faces against the shoulder cut on the inner part of the mitre on both boards. An advanced and a more intricate form of this joint used in the best finished work is:

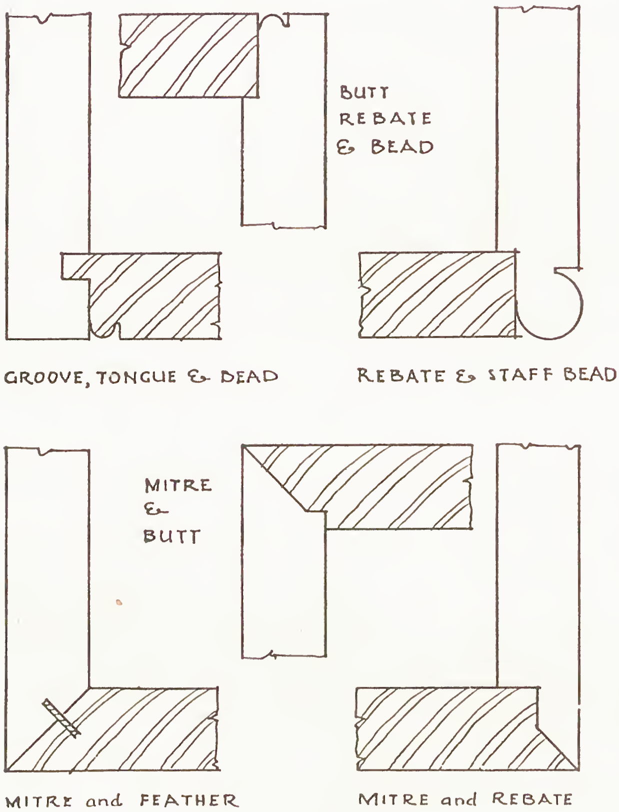


Fig. 103.—Corner joints.

The Groove, Tongue, and Mitred Joint, which has a tongue cut on the other board and the mortises marked out from them with greater accuracy than results from doing the job the other way round. The first thing to do, after the edges of the boards have been trued and squared, is to mark the thickness of each board on the other one and to run the line round both sides and edges with the steel square. If the square is accurate, and, of course, if it is not it is useless, and the planing of the sides and edges is square, then the line followed round all four sides of the board should end exactly at the point at which it began. If it does not, and it has been drawn with accuracy, then one or more of the four sides is out of the true and must be righted, as it is no use proceeding with the job until both boards are exactly true. Though it is true of all work in joinery to say that it is the preparatory work that counts most in the final success of the joint, it is even more true of the construction of the dovetail joint than any other. Consequently, until proficiency has been gained, too much time cannot be spent in getting the preliminaries exact.

Cutting the Tenons.—The next step is to mark out the tenons or pins. For this the dividers are required to space the wide parts on one line at one side of the board and the narrow parts on the other. Remember that the narrow parts of the tenons come on the *outside* of the finished job. The angle which experience has found to be best for the slope or bevel is 80°, and this should be marked on the end edge of the board with the bevel, the board being held in the vice. When the bevel lines are marked on the end, run them down with the square to the square line denoting the thickness of the other board. The same operation must be done with the thick sides of the tenons. Then with the board still in the vice saw with the tenon saw down these lines marked on the side of the lines on which the wood is to be cut away and *not* on the tenon side, or the finished joint will be loose. The saw must be held squarely, though an experienced joiner generally cuts down to the line on the nearest side first by depressing the handle of the saw, and when this line is cut to, he raises the handle and depresses the end of the saw blade, meanwhile looking at the line on the other side of the board. By this means he is assured of not sawing past the line. When the saw cuts have been made to the line on each side he saws a few strokes with the saw held level, taking great care not to saw below the cuts already made back and front.

The board is then removed from the vice and laid flat on the bench and the wood to be cut away is chiselled out in the manner described for cutting an ordinary mortise, *i.e.* a half at a time, cut at an angle towards the square line.

The bottom of the space between the tenons should then be pared smooth with the chisel, but the sides of the tenons should be left rough from the saw.

Cutting the Mortises or Sockets.—First hold the board with the tenons now cut on top of the other board laid on the bench, then mark the outline of the tenons on the other board. Now place the marked board in the vice and saw down the lines marked on the side of the line on which is the wood to be cut away. Cut away the wood with a narrow chisel in the same way as described in cutting the wood between the tenons. If the joint is very tight shave off the one mitre to fit into a groove cut in the other. This joint most effectively conceals any through-way, in the event of shrinkage, and owing to the number of faces at different angles, the glue is afforded a very firm hold.

Dovetailing.—The most secure form of angle joint is that known as the Dovetail, so called from the resemblance to a pigeon tail of the tongues cut on the end of one board to fit into open mortises cut out of the end of the other board. The tongues or tenons, being formed in the wedge shape with their narrowest part away from the other board, offer a resistance to any strain tending to pull one board from the other. This is the reason why this joint, or some form of it, is so much used in fixing drawer fronts to their sides. This joint in its simplest form has one objection, and this is that the end grain of both boards shows when the

boards are jointed together, and to overcome this *mitred* and *lapped* forms have been devised. If the dovetails are cut accurately there is no need for the use of glue; however, the joint is sometimes glued also.

A joint somewhat of similar character, though not a dovetail proper,

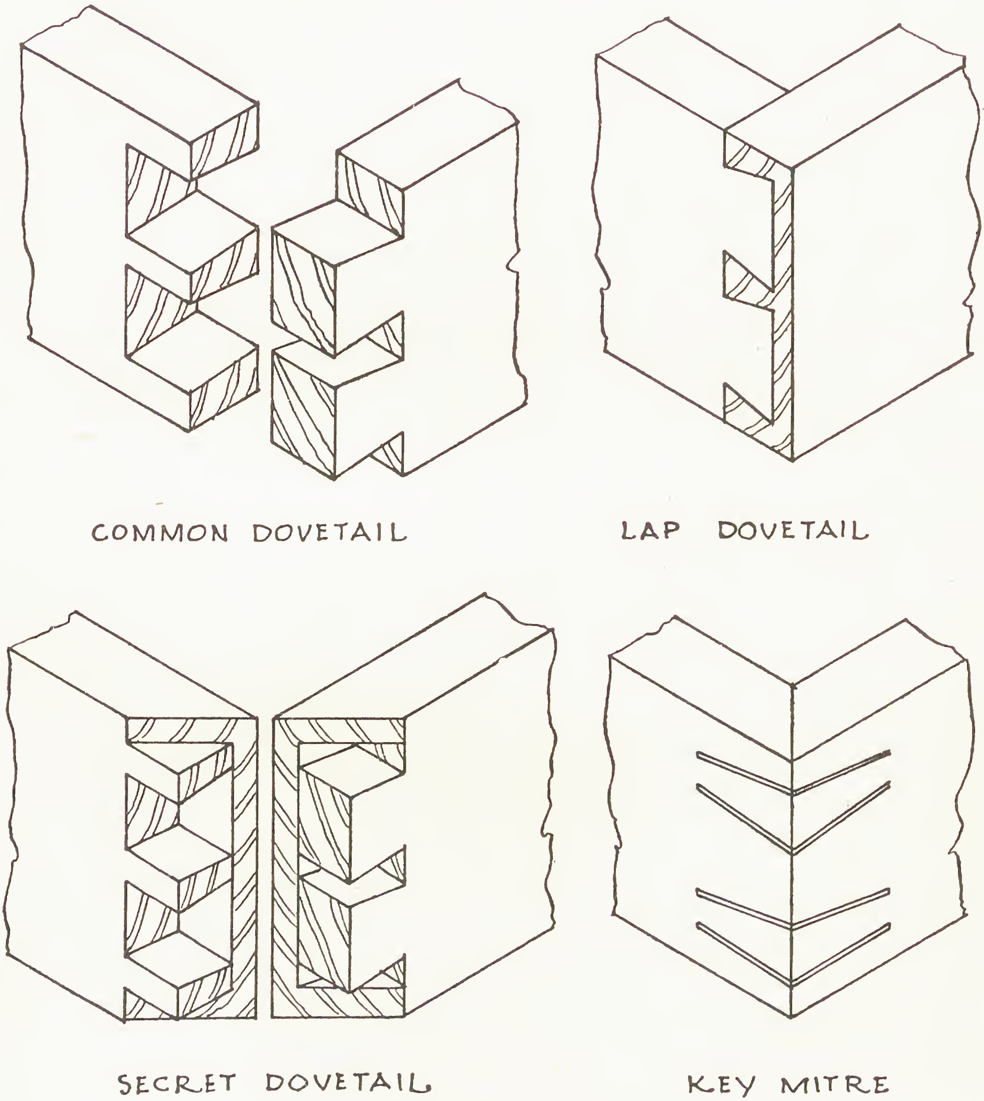


Fig. 104.—Corner joints.

is the *Corner Lock Joint*, in which the pins or tenons are cut rectangular. This joint is used in making cheap boxes, and if cut to fit tightly it has a decided resistance to tension, which it owes to a great extent to the fact that the tenons and the mortises are left from the saw.

Construction.—In constructing the dovetail joint it is advisable to

start by cutting the tenons or pins, as these can then be laid on corners of the inner angle of the board on which the mortises are to be cut.

In joining the two boards, first glue, then fix the tenoned piece in the vice and drive the mortised piece down on to it with the mallet, having first laid a strip of wood over the whole length of the joints. This jointing should not require any considerable force if the sawing and marking have been accurate, though at first attempts they very often have not.

The Secret Dovetail is generally a mitred dovetail, though it is sometimes formed as a lap or butt joint.

In the first the dovetails are cut in the same pattern as already described, but the corners of the outer edges of the boards are mitred to form an angle where they come together. This joint is used for plinths and skirtings in panelled work where it is required not to show the jointing or the end grain. This is a difficult joint to make, and to the beginner it seems as if he were prevented from cutting either the mitre or the tenons or mortises without one or other being cut first. The answer to this problem is to cut neither, but to cut rebates on the ends of both boards first, and then to cut the tenons on one board and to mark these when cut on the other board. The end shoulder and the corner are then cut splay at the angle required for the mitre on both boards—the bottoms of the sockets being square, *i.e.* at right angles to the board on which they are cut. The tops of the tenons and the mortises, being the rebated face, will be already square or at right angles.

The Lapped Dovetail is used when it is required not to show the end grain on one face, as in drawer fronts. In this joint the front is thicker than the side by the amount of the lap, otherwise the joint is formed in the same way as the ordinary dovetail. To make this joint a real secret dovetail the ends of the tenons should be covered by a lap on both boards.

It will be seen that considerable accuracy in marking and care in cutting is the secret of success in making all these forms of dovetail joints, and especially in the last two described.

ANGLE FRAMING JOINTS

The joint used for framing such fittings as doors and windows, and in fact the joint, or some form of it, which underlies most of the joiner's work, is the *Mortise and Tenon.* It is a form of joint used for fixing two pieces of wood at right angles to one another by cutting a tongue—the tenon on the end of one piece to fit into a slot cut out of the centre of the other piece. The width of the tenon should be one-third of the total width of the piece of wood on which it is cut. The mortise may be cut on the end of the timber, when it is known as *an Open Mortise,* or alternatively the tenon may be formed on the piece on which it is usual to cut the mortise, when the joint is known as a *Forked Tenon,* as in continuous rails in panelling or in doors when the rail is carried across the stile. Tenon joints are also cut double, haunched, stub and stump, as

explained later, but as the principles involved in cutting the mortise and the tenon are the same in one as for all, this is described in a general way first.

The Mortise.—Cutting the mortise was in the old days performed by hand, and it is still so cut in the best craftsmanship, the brace and bit being used to start the work by boring halfway through on each side and then cleaning out with chisels, a broad one for the flat sides and a narrow one for the ends. Since the introduction of machinery, however, mortises are generally cut by a mortising machine, which can be adjusted to the width of cut required.

If the pieces of wood to be joined are the same thickness, the width of the mortise is one-third of the width of the wood, but if the thickness of the piece in which the mortise is to be cut is greater than that on which the tenon is to be cut, then the width of the mortise is one-third of the width of the piece on which the tenon is to be cut. For marking the two parallel lines giving the width of the mortise, a mortise gauge is used, which is a similar tool to the ordinary marking gauge, but having two marking teeth instead of one. This consists of a circular rod encased in brass running through an ebony shoulder faced with brass. The outer marking tooth is fixed and the inner one is adjustable. The shoulder is movable along the rod, and is provided with a screw for adjusting and fixing it at the distance required to give the correct markings.

Cutting the Tenon.—First mark on a line all round the end of the piece of wood the same thickness as the width of the piece which has the mortise cut in it. Square this line round the square, and as before described, make certain that the line ends at the point at which it began, because it is essential to the proper fitting of the joint that the shoulder of the tenon should be square and an equal depth from the end of the piece of wood.

Then with the mortise gauge (see above) set to give the required width of tenon, mark the end and the top and bottom of the tenon. Place the wood in the vice and saw down on the outside of the tenon marks, starting with an angular cut and finishing square. Then removing from the vice cut the shoulders with a square cut. To undercut the shoulders will tighten the joint on the face and make it look a better joint at first possibly, but if the wood shrinks, as most wood does under modern seasoning conditions, it will be the outside of the wood that will shrink most, with the result that the joint will gape. Some joiners saw the inside shoulder a little lower than the shoulder which is to show on the face of the work, such as, for example, when the tenon is for a cupboard door which will be mostly kept closed. However, those are merely tricks to conceal bad workmanship, as if the shoulders are cut exactly equal and perfectly square, it must fit tightly all round, and there is no need for any additional precaution beyond one to counteract shrinkage. This is effected by the method of pinning, in which the tenon is pulled through the mortise, with the result that the shoulders of the tenon slightly compress the fibres of the cheeks of the mortise. This method consists in boring a

hole through the sides of the mortise and through the tenon for a wood pin, but instead of boring this hole after the joint is put together it is bored first through the sides of the mortised piece, then the tenon is put into position and the hole marked on the tenon, which is then withdrawn and the hole bored slightly nearer the shoulder of the tenon than the marking, with the result that when the joint is again assembled and the pin driven it pulls the joint closer together by reason of the pressure the pin exerts on the side of the hole in the tenon.

For outside work the joint should be painted before being assembled, and for inside work it is glued only. Further, as there is more likelihood of the tenon shrinking on outside work, it is customary to wedge it with wedges driven in above and below the tenon from the end face. To accommodate these wedges the mortise should be slightly wider than the tenon, and the corners of the end of the tenon should be slightly pared with the chisel before assembling the joint. The wedges are then driven in when the joint is assembled, just sufficiently tightly fitting to compress slightly the fibres of the tenon. No great force is required for this, but just sufficient to counteract future tendencies to shrink.

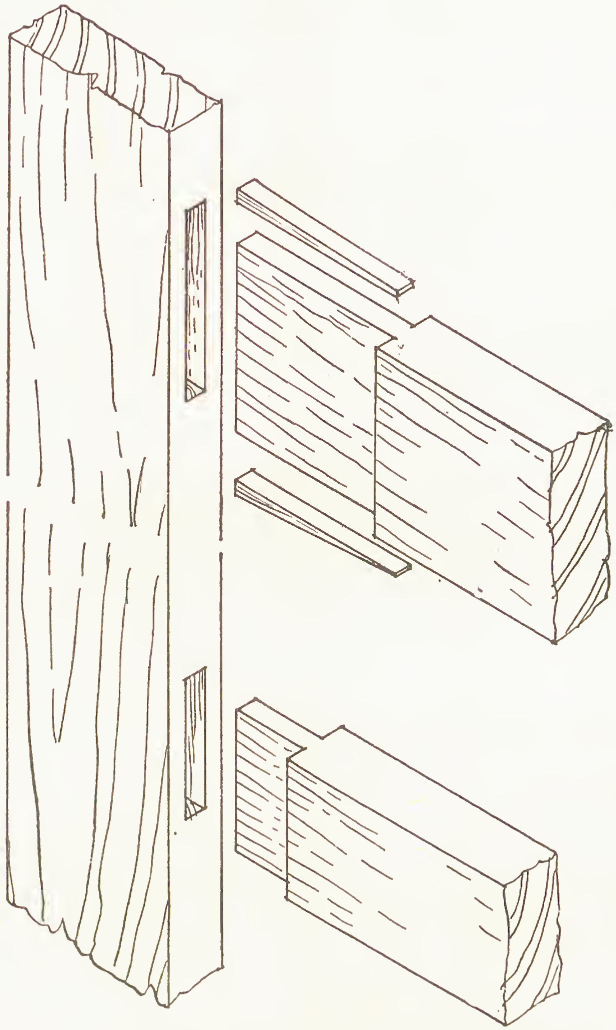


Fig. 105.—(*Top*) Ordinary mortise and tenon with wedges. (*Bottom*) Stub tenon.

The Parts and Proportioning of the mortise and tenon are of importance (see Fig. 105).

This joint is made between the two pieces of wood 1 and 2 at right angles by cutting a tongue known as the *Tenon* on piece 1 to fit into a *Mortise* on piece 2. The abutting faces of piece 1 at each side of the tenon are called the *Shoulders*, and the faces against which these abut

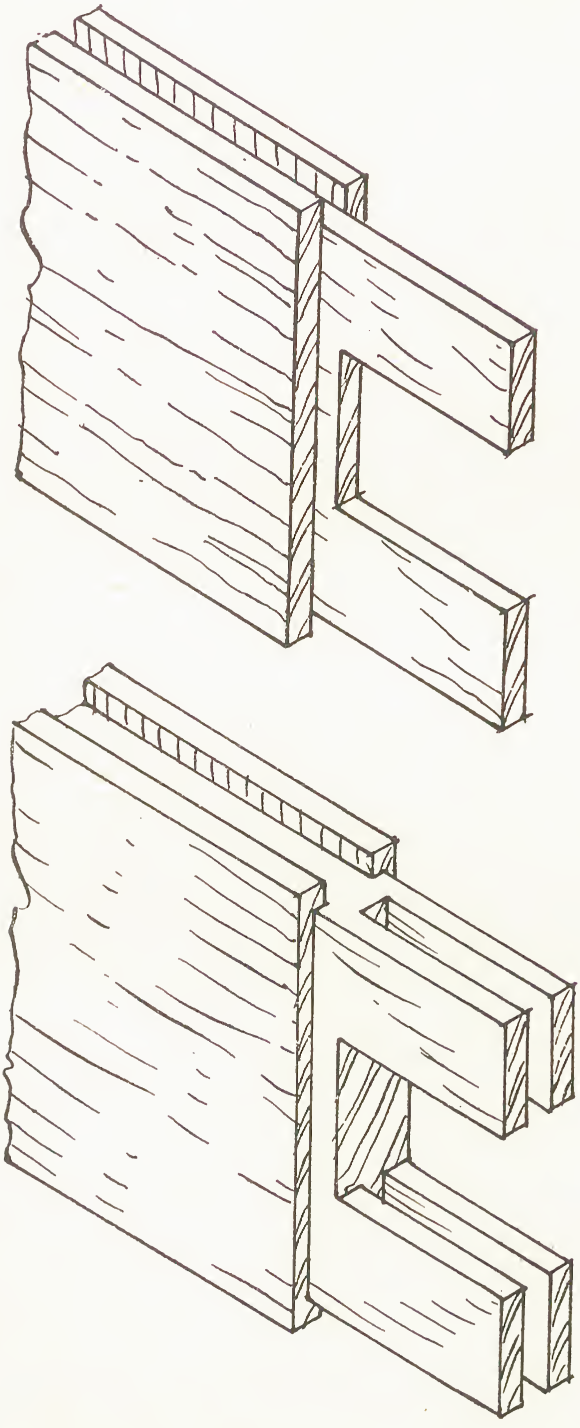


Fig. 106.—(*Top*) Pair of single tenons for deep rail. (*Bottom*) Pair of twin tenons for deep thick rail.

on piece 2 are called the *Cheeks*. The base of the tenon is called the root; and at the side of piece 2 and through the centre of the flat side of the tenon is driven a wood pin, which should not be more than one-fourth of the thickness of the tenon in diameter. This pin is not always required, and in some instances it may be replaced by wedges, and in others, neither are required, and it is bored at a point one-third of the distance from the shoulder to the end of the tenon.

The width of the tenon is one-third the width of the piece A, but in length it should be cut just short of the depth of the mortise; consequently, it will be seen why it is so important that the shoulder should be cut exactly square and in line.

The Open Mortise and Tenon, which is sometimes called the *Tenon and Slot,* is used for jointing pieces of wood at their ends, and as one side of mortise is open the pin is essential. This is a framing joint used in rougher work such as, for example, outside solid door frames in the joint between the head and the posts.

Double Tenons in thick framing should have the shoulder cut to a depth of about one-sixth of the thickness of the framing and the width of the inner shoulder should be one-quarter of the thickness of the framing.

The Double Tenon is to be distinguished from a pair of single tenons, as in the first the tenons are side by side in the thickness of the piece of wood on which they are cut, whilst in the second they are formed one above the other. This joint is used in framing thicker timbers together at right angles and in such positions as those where it is required to cut away the wood at the centre of the tenon, as in a lock rail to a door for the insertion of a mortise lock and where, if a single tenon were used, a great part of it would be cut away for the lock.

In cutting the tenons for the double tenon, as with the single tenon, all the saw cuts in the length of the timber should be made first. The inner tongue of wood between the tenons in their width is bored through with a brace and bit just above the shoulder line and afterwards pared out with the chisel. In the *Haunched Double Tenon* the cuts at each side of the central cut-away portions are not continued down to the shoulder line, so that the base, or abutting face of this portion of the joint, is raised above that of the shoulders forming a haunch.

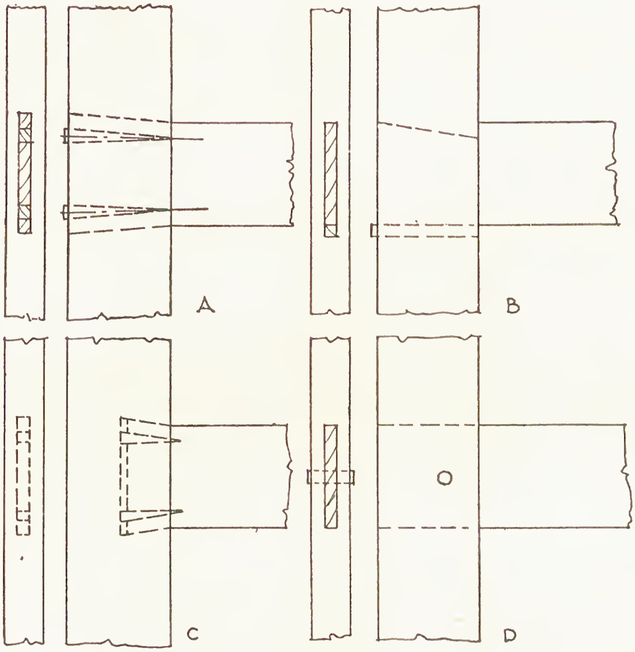


Fig. 107.—Special methods of securing tenons.

A. Wedges inserted in tenon.
B. Dovetail tenon with key.
C. Fox-wedged tenon—when tenon is hammered up wedges are tightened.
D. Draw-bore pinned tenon.

Single Tenons are also *Haunched* for angle joints which it is not desirable to form as open or slot tenons, as in jointing the top rail to the stile of a square framed door. The tenon is first cut in the usual manner, and then has the top corner cut away, leaving a shoulder and part of the tenon of the full width which forms the haunch. This joint is generally wedged from the end of the tenon. The width of the tenon here is half its net width after grooving.

Single Tenons in Pairs are cut one over the other with a haunch between them and another under the lower tenon. This joint is used in framing the bottom rail of a square-framed door, where the increased width of the timber would require too great a width for a single tenon, but double tenons side by side are not required. In an ordinary

door, having a bottom rail of 11 inches deep, the lower haunch would be 2 inches.

A Bare-faced Tenon is really a halving under another name, on account of its use in a different position from that for which halvings are generally employed. It is used in jointing rails to stiles of doors in which the rail is not so thick as the stile.

The Halved Tenon, on the other hand, is a joint used when the two rails meet in a mortise cut in an upright. The tenons are cut in the ordinary manner and then halved in their width, so that together they just fill the full-size mortise.

The Tease Tenon.—Whilst the last described tenon was a form of halving for jointing two rails in one line, that now to be considered is one used for jointing two rails within an upright and at right angles to each other. The tenon on each rail is cut first in the ordinary manner, and then a notch is cut out of the top half of one tenon and of the bottom half of the other, a haunch being left on both. Thus the tenon lies over the other within the mortise cut in the upright post. To hide the end grain of these tenons they should be mitred.

The Dovetail Tenon is a halving devised for resistance to pulling apart strains in the rails halved. It is used where a transom in a window is jointed at the mullion and continued across it. The dovetail joint shows on the surface, this joint being more in the nature of a halving than a mortise and tenon. It requires wedging with folding wedges, and to accommodate these the mortise in the upright must be cut out wider than the two halved tenons.

The Box Tenon, also termed the angle tenon, is used for jointing corner posts to kerbs. In sawing the tenons are cut right across, leaving a square tenon at the angle of their junction, the two tenons being formed at right angles to fit into a mortise cut in each kerb timber.

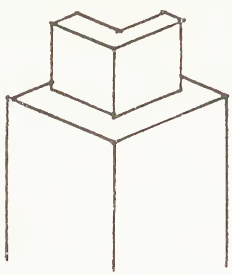


Fig. 108.—Box tenon.

The Tusk Tenon belongs to the carpenter's work, under which heading it will be found fully described. It is designed to give support to weights from above, as in those imposed upon floor joists, and in consequence the tenon is cut in such a manner as to give several horizontal bearing-surfaces. See Chapter 3, Volume III.

Key Tenons.—Various forms of keys are used for jointing an upright, such as a door post to a circular head. These may be separate pieces of hardwood, when they are termed *Keys,* or they may be tenons cut on the upright to fit into a mortise cut in the curved timber, when they are known as Hammer-head Tenons. In these the tenon is cut with a wedge-shaped enlarged head, with shoulders wider than the tenon itself to act as hooks, holding into the mortise cut

in the curved portion to receive it. The top part of the mortise to receive the head of the tenon is cut slightly deeper, so that wedges may be driven into the space under the hammer-head to tighten the joint.

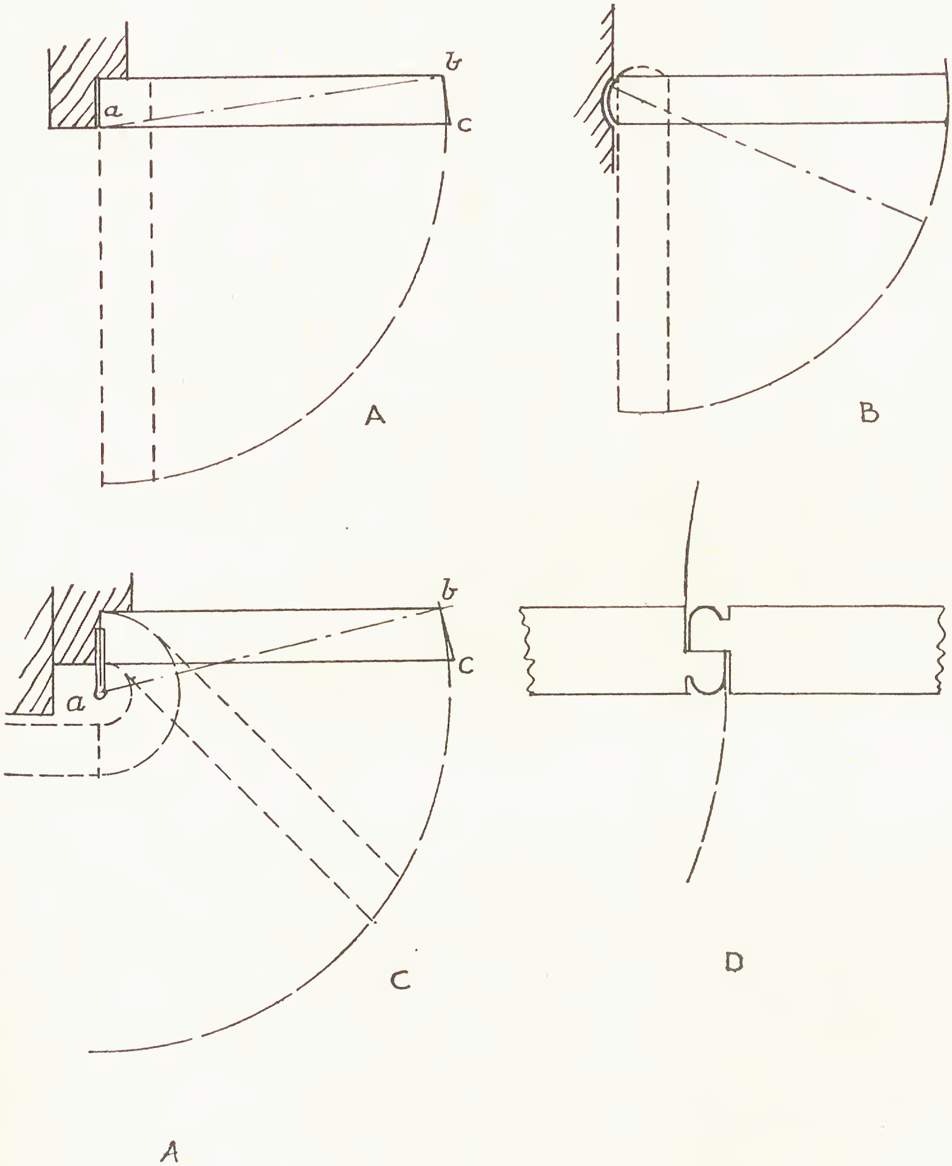


Fig. 109.—Shutting joints.

A *Hammer-head Key* is a separate piece of wood in place of the tenon last described, having both its ends shaped into hammer heads connected by a thinner strip representing the tenon in the hammer-head tenon joint. This key being separate from both timbers, the upright and the curved

head, the mortises for its reception must be cut in both timbers ; and as the connecting strip might be of insufficient width to resist satisfactorily any transverse or shearing strain, tongues are also inserted on each side of the hammer-head key let into grooves cut in both the post and the curved head. The key is wedged both at the top and the bottom in the same way as that described for the wedging of the hammer-head tenon joint.

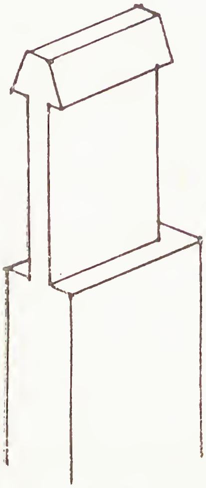


Fig. 110.—Hammer-headed tenon.

A Fox Tenon is one into the end of which hardwood wedges are partly driven, which, when the joint is assembled, are driven into the tenon by contact with the interior of the stub mortise, *i.e.* one which is not cut right through the timber. The mortise is cut slightly dovetailed, and the tenon, being expanded as the wedged pins are driven in, completely fills the dovetailed mortise, with the result that the joint is useful in resisting tension.

A Form of Fox Tenon and Loose Key is used in jointing sharp angles in framing, such as sometimes occur in transom lights over doors. A halved mortise-shaped dove-tail is cut on the side face of both timbers to be joined, and into the ends of the key are driven wedge-shaped pins to expand its ends to fit the dovetail mortise.

A Stump Tenon is one having double shouldering for the purpose of giving extra strength to transverse or shearing strain. Thus the tenon at its root is wider by the amount of a second shoulder on each side than the remainder of its length.

SHUTTING AND HINGING JOINTS

These consist of some form of rebate, and are used in the junctions between doors and windows and hinged leaves of table tops, though they are not joints in the usual sense of the term, in that they

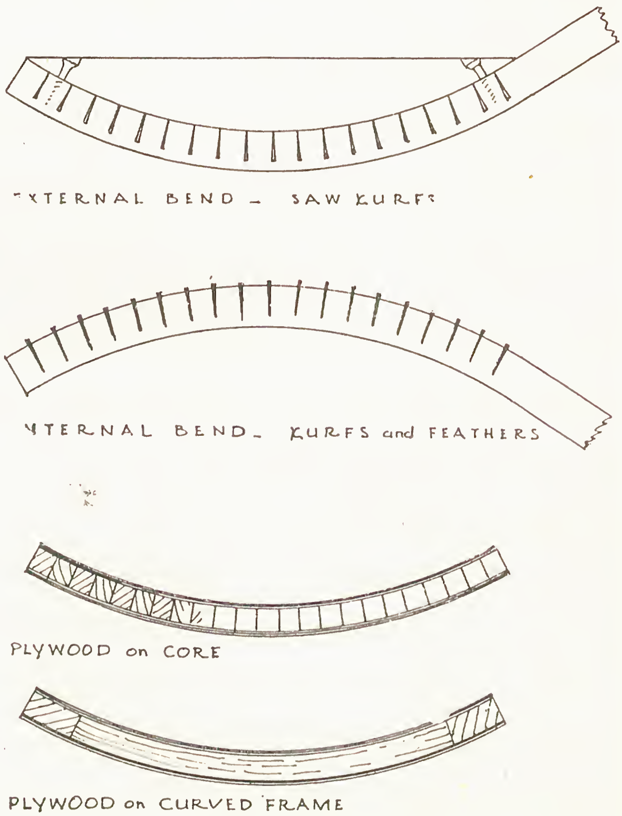


Fig. 111.—Bent work.

are not fixed to prevent the material on which they are formed from coming apart.

Plain Rebate.—In ordinary-class construction the square window sash or the corner of the door stile fits into a chase cut out of the corner of the frame. This chase is termed a *Rebate* (pronounced rabbit).

The Shutting Joint.—In this joint the rebate on the shutting stile—*i.e.* the one not carrying the hinges of the door—is splayed at an angle of 90° to the line drawn from the hinged corner to the opposite corner of the door on the shutting face. The reason for this will be clear if one draws the door in a frame and then strikes an arc of a circle with one leg of the compass on the hinge as centre and the other on the corner of the door within the rebate as radius. If the door is a very thick one, it will be found that the arc of the circle cuts into a square rebate, and if so made it would prevent the door from opening. Hence the splay

Hanging Stile Joints consist of a curved groove where the door stile is on a pivot. The frame is grooved out to take the rounded edge of the stile, the curve on the stile being of a greater radius than that in the frame.

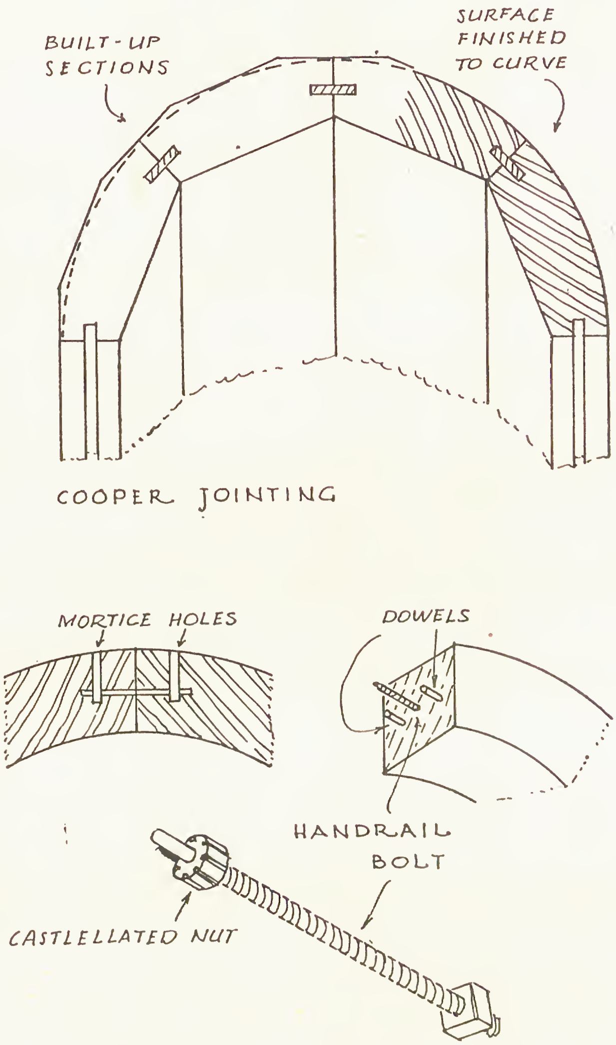


Fig. 112.—Jointing built-up curved work.

Bead and Rebate.—The meeting rails of doors are rebated to fit one against the other, and to cast a shadow over the junction a bead is turned on the outside corner of each stile.

The Bead and Splayed Rebate Joint is one in which the rebate is splayed for the same reason as above described; its application here

being to pairs of doors, circular in plan to open outwards. This is used mostly in cabinet making.

The Hook Rebate is one in which the rebate is undercut on one stile or post, the other stile being cut to the shape required to fit into this undercut rebate. Where two sashes, both opening, are formed in this manner, the joint must be splayed as well as hook rebated.

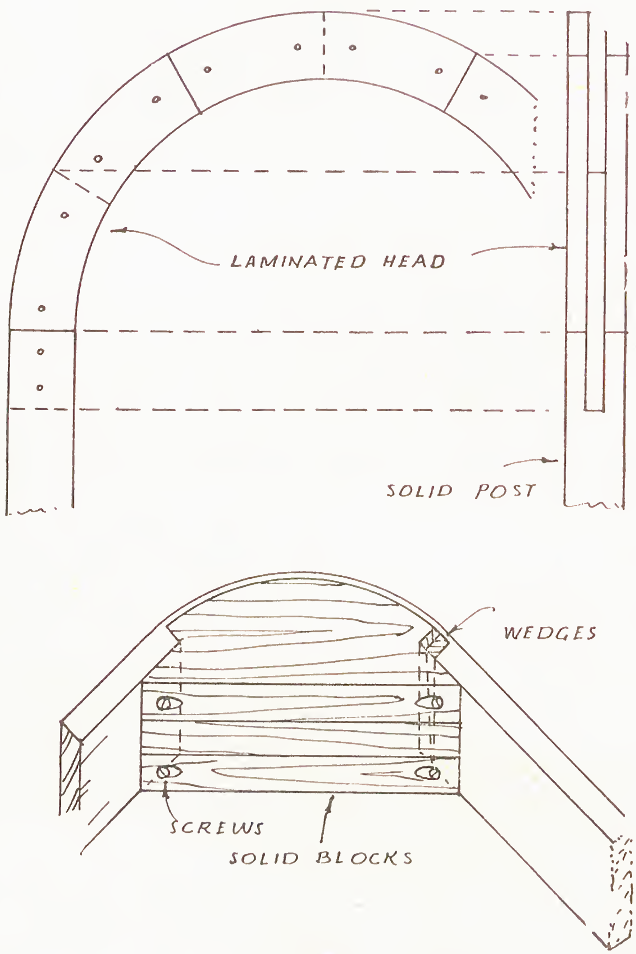


Fig. 113.—(*Top*) Laminated built-up curved head to frame. (*Bottom*) Short radius external angle with block backing.

Throatings and Weather Stops are not really joints at all, but as they concern the treatment of the shutting surfaces of doors and windows they are included here.

In order to close the through connection from the outside to the inside, a projecting bead is turned on the inner corner of the stile to fit into a groove cut in the frame for its accommodation.

Another method of effecting the same purpose is to form hollow semicircular grooves in both faces, forming together a circle.

Cabinet Doors.—The shutting joint is concealed in cabinet doors by fixing a moulding, known as a *Bolection Mould*, on the outside of one stile and projected so that the other stile shuts in behind it. It is, of course, necessary in opening such doors that the one having the moulding fixed to it must be opened first, and the other cannot be opened without the first.

NAILS AND SCREWS

Though nails and screws are not required to secure the joints used in joinery, and properly are more used by the carpenter than the joiner, yet as nails and screws of smaller types are used by the joiner, the following few descriptive notes are included.

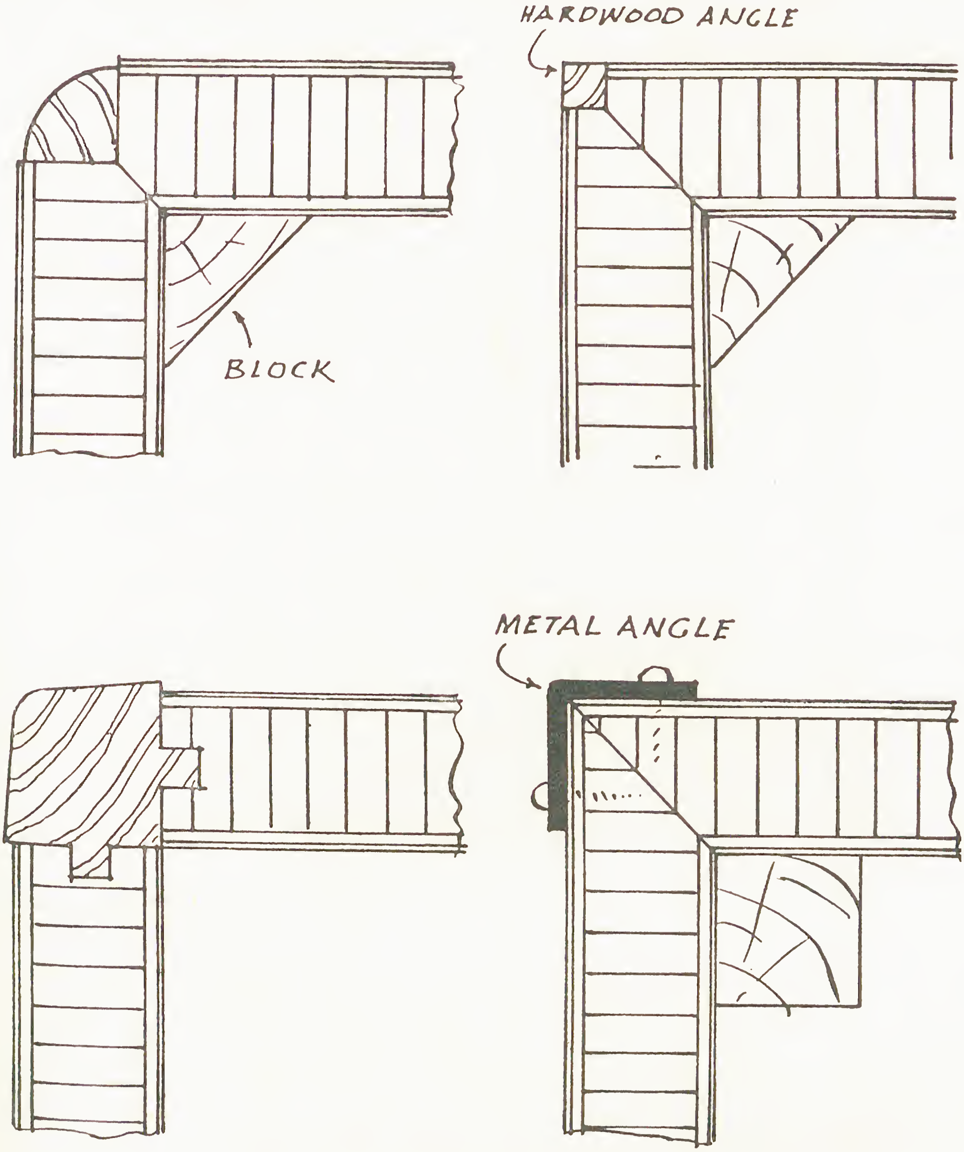


Fig. 114.—Angle joints for laminated board.

The Cut Nail is used for flooring, and shorter nails of the same shape are used for finer work, and are known as sprigs.

Clout Nails, short and with flat circular heads, are used for felting to roofs, and for fixing the ends of sash cords against the side of the sash.

Oval Wire Nails of the smaller type are used by the joiner for framing, and the heads are generally punched below the surface or turned over.

Wrought Nails are used where more strength is required.

Tacks are small, short, and light nails used in furniture making in fixing the upholstery.

Sprigs or Glazier's Nails are short, pointed pins without heads, and are used for securing the glass of a window into the rebate of the frame to hold it in position for puttying.

Needle Points are used in repair jobs, for holding together a fracture until the glue has set. Being slender and without heads, they are not readily seen when driven in.

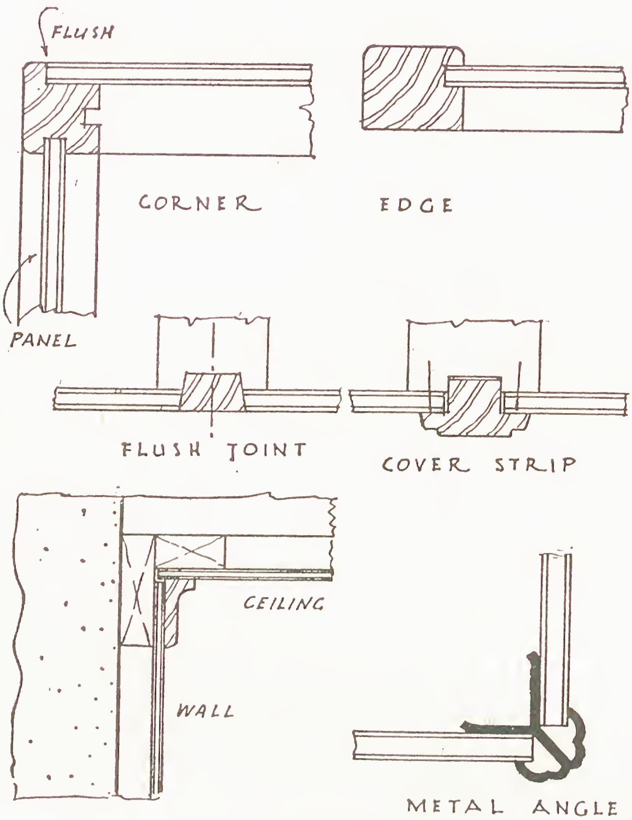


Fig. 115.—Fixing plywood.

Screw Nails are nails with a spiral turn on them, but are driven with a hammer instead of a screwdriver.

Screws are more used in finished work by the joiner than nails, but the screws are of course of a lighter kind than those used in carpentry. Brass screws are used where a good appearance is desired, when they are frequently counter-sunk and fitted into cups. Screws are also made of iron, copper, and gun-metal, and the heads may be flat or rounded, and finished either polished, japanned, oxidised, or nickel-plated.

A Dowel Screw is one having two spirals at each end, and is used for screwing one piece of wood butt end on to another, as in the junction of circular or rounded handrails.

The Handrail Bolt is another form of screw used in jointing a handrail which, by reason of its shape, could not be satisfactorily jointed by means of the dowel screw. This consists of a bolt having both ends cut with spirals for nuts. The head of the nut on one end is square. This nut is let into a mortise cut in the underside of the handrail after a hole has been bored from the end of the handrail to a point just past the mortise. The bolt is then screwed into the square nut. The nut on the other end of the bolt is a circular nut having chases cut in its edge to enable it to be tightened by means of a handrail punch. The circular nut is placed at the end of the hole bored in the other piece of handrail similarly through a mortise, and when the two pieces of handrail are put together, the bolt

is projected into the hole cut in the second portion and touches the circular nut. As this is punched around, it engages the bolt end and pulls the sections of handrails together.

Fibre Plugs, devised for fixing woodwork to brickwork without wood plugging, are much better than wood plugs, being easier to fix and having a stronger grip. Wood plugs are liable to shrink and rot. A hole is bored in the wall material by a cold chisel with a special point which cuts as it is twisted, and a fibrous tube is then inserted in the hole so bored. As the screw is driven into the fibrous tube the sides of the tube afford it a bite.

Metal plugs are made, chiefly for use in damp situations, with an edge that forms a cup into which the head of the screw settles when driven.

FIXING FOR JOINERY

Grounds.—The brickwork opening for a doorway is first framed round with grounds to which the door linings are fixed. These grounds are strutted apart with *Backings* dovetailed into their edges and run through the opening from back to front. Both grounds and backing are nailed to pallets of wood let into the brickwork joints. As there is a prejudice against these wood pallets being built in as likely to originate dry rot, *Coke-breeze Bricks* and *Pumice Bricks* which can be nailed into equally well are now preferred. A wood fixing brick of the same size as a clay brick and used for this purpose is termed a *Nog.*

Wood Plugs of cleft yellow pine or deal are used for nailing and screwing joinery to. They are tapered with the axe, and the taper is given a slight twist, as this has been found to improve the hold

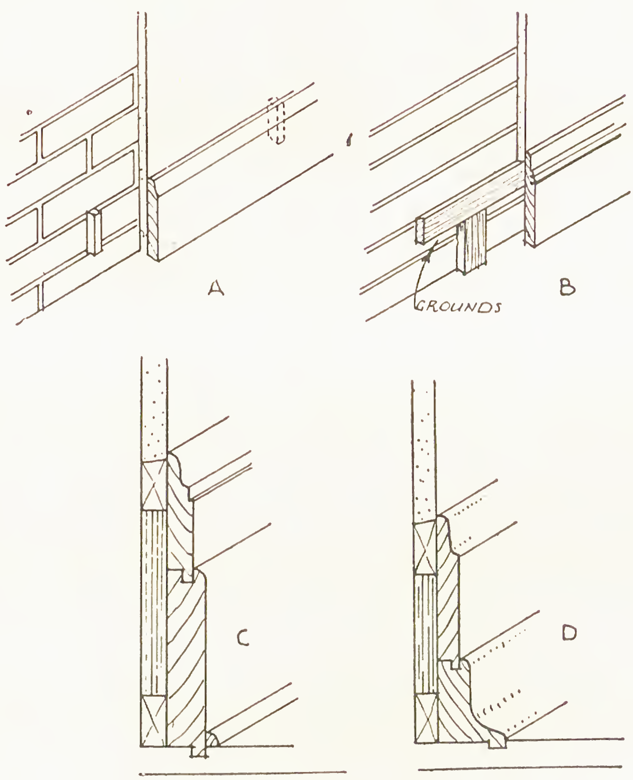


Fig. 116.—Skirtings.

A. Fixing direct to wood plugs—cheap but not recommended.
B. Fixing to grounds.
C. Deep skirting in two pieces.
D. Skirting designed for easy cleaning.

of the plug on the brickwork or masonry. Patent fibre or metal plugs or fixing bricks, are much better, for the reasons already stated.

Skirtings are fixed to two grounds in their height—one at the base $2 \times \frac{3}{4}$ inch, and the other near the top, $1\frac{1}{2} \times \frac{3}{4}$ inch. These are dovetail halved into the grounds.

The Jamb Linings, i.e. those at the side of the opening, and the soffit lining are nailed to the backings mentioned above.

Shelving fixed direct to the walls is supported by a *Shelf Nog*, generally about 3 inches wide, let into the brickwork. To give a lighter appearance to this from the front it is generally tapered to 1 inch.

Wooden Brackets are also formed to support shelving, having a wall plate at the back, which is nailed or screwed to the wall, and at right angles to this a horizontal board braced with a diagonal board let into a bevelled chase in its underside.

WARPING PREVENTIVES

As was explained in the chapter on Timber (Chapter 2, Vol. III), timber will continue to move after it has been fixed unless it has been very thoroughly seasoned, and even then it depends to a great extent upon the method by which it was sawn from the log, as there is more shrinkage in sapwood than in heartwood. A wide board cut right across the centre of the log will shrink more in thickness at the outsides than at its centre ; whilst a board cut from the outside of the log will curl outwards or warp at its edges.

Consequently, to prevent this tendency in wide boards, the following devices are made use of :

Two single tenons one above the other as already explained will prevent the tendency of a wide rail in panelling to twist or to split.

Battens are let into the back of panels composed of several widths. The batten is splayed at its edges to fit into a dovetailed groove. But where it is not desirable to cut into the material of the panelling, a method known as the *Batten and Button* is employed. The batten is rebated along its edge, and wood buttons rebated to fit are screwed on each side of it to the boards of the panelling alternately.

Boards which it is particularly desirable to retain in their flat condition, and composed of two or more pieces, such as, for instance, large drawing boards, are braced along their backs and at right angles to them by battens screwed to them by means of screws working through slots. By this means, should the boards shrink and tend to pull apart, the screws may be adjusted.

Such boards are also stiffened at their ends by means of wooden clamps tongued and grooved to them. In addition they may be mortised to the clamps ; and where the clamp is run all round the composite board, as a frame, it is mitred at right angles and keyed.

If the boards are very thick, a metal bolt is run through holes bored for it, and the bolt is fitted at one end with an adjustable nut.

Very wide boards may be caused to resist warping on their own account by being plough grooved at the back along their lengths.

PANELLING

Panelling is a formation on wood consisting of a flat surface, generally in one board, surrounded by a frame consisting of a base, stiles, and a top rail, and in some instances, as for example, in doors, there may be one or more intermediate cross-rails.

Except in the best class of workmanship, panelling has been superseded by cheaper methods. This is mainly due to the fact that the workmanship is rather intricate, and that panels of any width require really well-seasoned wood, which is more difficult to obtain now than it was.

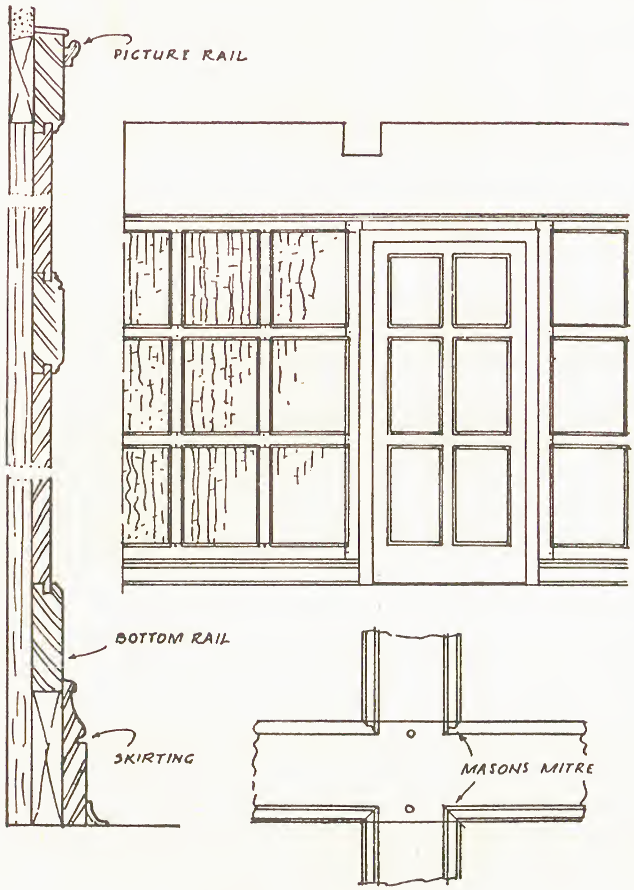


Fig. 117.—Solid panelling.

Panelling is best understood from an explanation of the construction employed in making panelled doors, and the detailed account of these will be found later. The difference between panelling fixed against a wall and panelled doors is that the first is finished on one side only and the second on both sides.

The basis of panelling is a framework of stiles and rails having thin flat boards framed into them, a base and a capping which may be moulded and projected to form a cornice. The base is usually the skirting, and there may be only one or any number of horizontal rails according to the height of the panelling and the design required. The proportioning of the panels may be a matter of taste, but it is generally accepted that

square (in area) panels do not look well. A satisfactory proportion is one in which the height is one and three-quarters the width.

Square Panels.—This term does not refer to the shape of the panel in area, but to the fact that it has a plain flat face, and that the stile is finished square at its junction with the panel. Square panels may be recessed on both sides of the stile ; or recessed on only one side ; or flush with the stile on both sides.

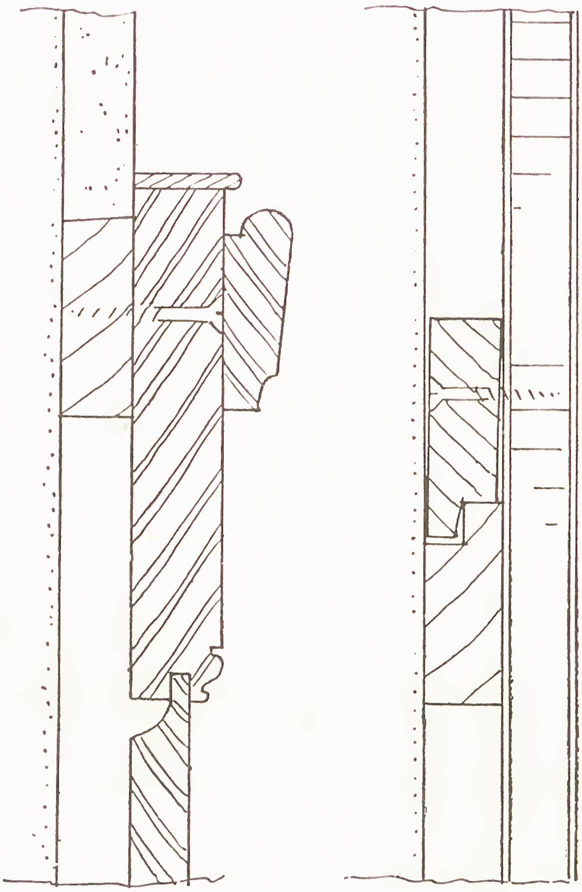


Fig. 118.—(*Left*) Panelling screwed to grounds, screws covered by skirting, picture rail, etc. (*Right*) Concealed fixing by turn-button engaging with rebated batten.

With the flush panel having a square joint and the flush on one side also having a square joint on that side on which it is flush, a bead is worked on the edge of the panel flush with the face to conceal any opening of the square joint caused by possible shrinkage.

Raised Panels.—The surface of the panel is often raised beyond that of the stiles, when it is either chamfered or moulded back to the groove in the side into which it fits.

Mouldings of a heavy design are planted on the face of panels, and projected beyond the face of the stiles.

Dado Panelling is generally run up the wall to the height of the architrave over the door head ; whereas, if only about 4 feet 6 inches in height, it is termed *Wainscoting*, and is finished with a moulded rail termed the chair rail ; the supposition being that this rail, coming at the height of the top of the backs of the chairs, will protect the wall. Wainscoting is often formed of matched and V-jointed boarding, which is not properly named panelling. Panelling is sometimes used to form a division or partition between the rooms, and must then be finished on both sides.

Panel Mouldings.—In the older types of panelling the framing was often very heavily moulded, and this old work is to be distinguished from

more modern by the fact that the mouldings rarely intersect, those on the vertical framings being butted against a square portion of the rail prepared for that purpose by " running out " the moulding on the lower edge of the horizontal rail. This running out is a sort of fading out of the cuttings, making the detail of the moulding until a square arris is obtained, and obviates the necessity for mitres. The upper arris of the horizontal rail was generally splayed and the moulding on the upright was scribed down on to it.

Ply Panels.—Panels in modern work are formed of plywood of 3 or more laminations of thin wood pared off the log in its length in the manner described in the chapter on Timber (Chapter 2, Vol. III). Panels so prepared are not so liable to warp or shrink, owing to the grain in each alternate thickness making up the plywood being reversed. Consequently, wider panels may be used with greater security, and any grain may be obtained by selecting whatever is desired for the outside sheets of veneer. The durability of plywood depending mainly on the glue, any objection to its use in the past has now been removed since the great improvement in quality of the glues now to be obtained.

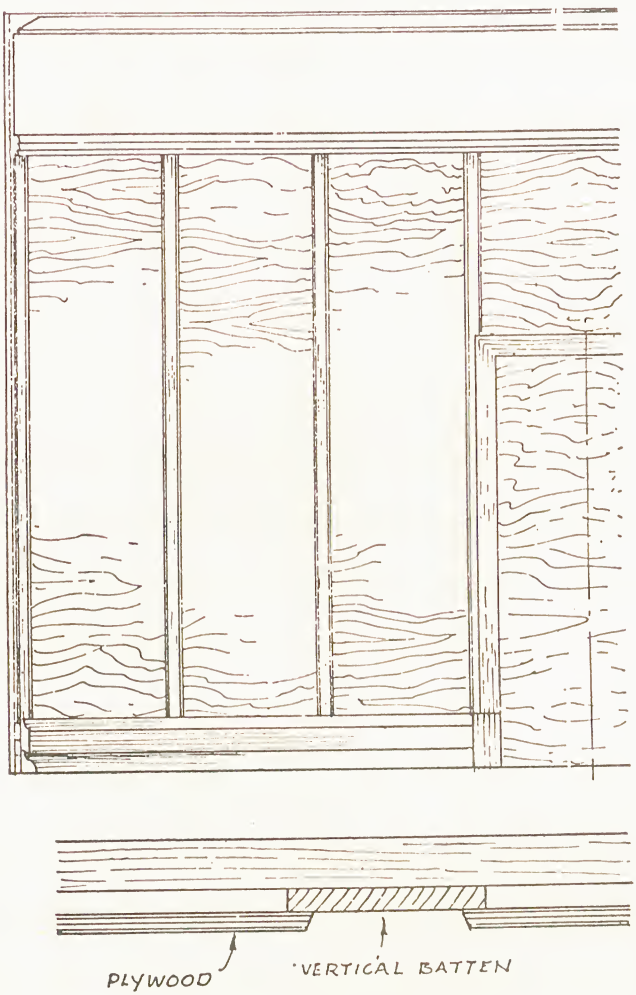


Fig. 119.—Vertical plywood panels.

Ready-made Panelling is obtainable at approximately half the price of specially made panelling. The framing is of 1-inch material, and the panels are laminated plywood veneered with figured boards. The panels are secret-fixed by means of metal clips, which are screwed to the walls at about every other panel. These are covered with the muntins, which are recessed to receive them. The upright grounds are nailed to the wall at every other muntin and at the angles of the room.

The cornice is fixed to the top deal rail that finishes the top of the panelling.

PLYWOOD AND BUILT-UP BOARDS

These materials enable very large panels to be used without the laborious work of building-up by the old hand methods, and with efficient fixing the risk of warping and shrinkage is less. The sheets veneered with costly hardwoods are much cheaper than similar areas of solid hardwood.

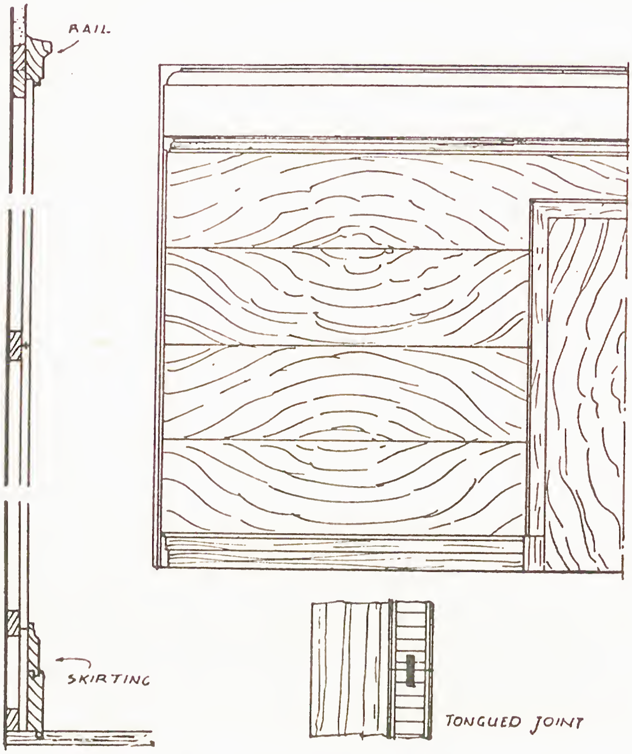


Fig. 120.—Panelling in veneered laminated board.

Plywood.—Plywood consists of three or more thin sheets of natural wood glued together. There is always an odd number of sheets—3, 5, 7, or 9—so that stresses are evenly distributed through the plies. Where more than three plies are used in the thickness the sheets are called multi-ply.

Plywoods are obtainable of birch, alder, Oregon pine, and Norwegian pine. They are also made with hardwood veneers on one or both sides—the chief veneers being oak, mahogany, and walnut.

Sizes vary according to the wood. There is usually no difficulty in obtaining sizes up to 60 inches long and 48 feet wide, but with some woods sizes up to 60 × 60 inches and 84 × 30 inches are obtainable.

The number of plies do not indicate the thickness. For example, a three-ply may be thin or thick according to the thickness of the middle ply, and a thick three-ply may be thicker than some multi-plies. Plywood should be specified by thickness, quality, or grade and type of wood or veneer.

Grades.—Four grades or qualities are specified in B.S. No. 531. Grade 1 is the best, free from knots on both sides; Grade 2 is of best quality, free from knots on one side, the other having a few small knots; Grade 3 has a few very small knots on one side and a few small knots

on the other; Grade 4 has small knots on both sides, though usually one side is better than the other.

The usual thicknesses are:

Three-ply: $\frac{1}{8}$ inch to $\frac{3}{16}$ inch and 3 mm., 4 mm., $4\frac{1}{2}$ mm. Also $\frac{1}{4}$ inch and 6 mm.

Four- and five-ply: $\frac{1}{4}$ inch or 6 mm., $\frac{5}{16}$ inch, $\frac{3}{8}$ inch or 8 mm., 9 mm. in five-ply.

Seven-ply: $\frac{1}{2}$ inch or $12\frac{1}{2}$ mm.

For wall panelling $\frac{3}{16}$ inch is commonly used with grounds not more than 20 inches apart, or $\frac{1}{4}$ inch if grounds are wider spaced.

For ceilings $\frac{5}{32}$ inch or $\frac{3}{16}$ inch.

For stressed skin work, such as partitions with very light framing in which the plywood sheeting is stressed, thicknesses of $\frac{1}{2}$ inch to $\frac{7}{8}$ inch.

For flooring the usual thicknesses are $\frac{3}{16}$ inch or $\frac{1}{4}$ inch. Special veneered flooring squares are made in squares of 9 inches, 18 inches, and 36 inches.

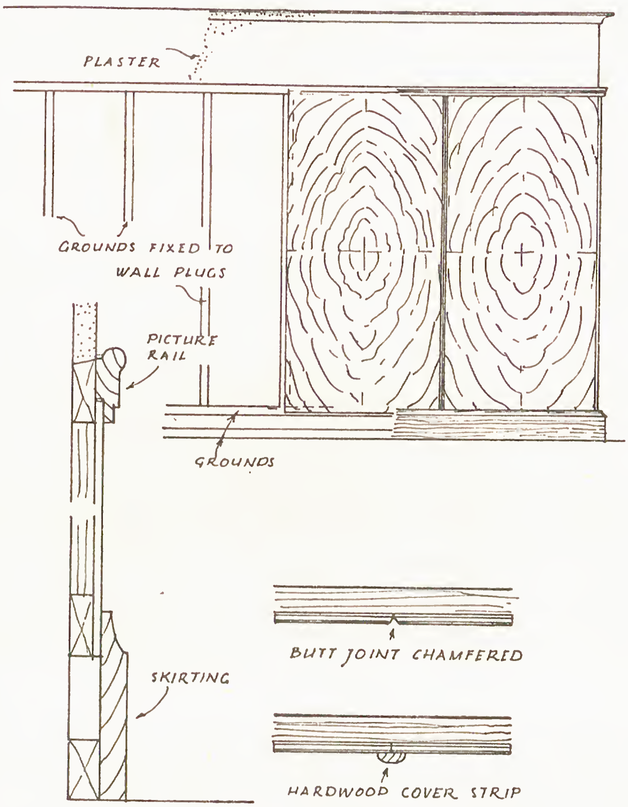


Fig. 121.—Quartered veneer plywood panelling.

Sheeting Walls with Plywood.—Where plywood is used as a wall covering to brickwork or concrete, and not as framed panelling, it is nailed to deal battens, which should be not less than $1\frac{1}{2} \times \frac{5}{8}$ inch. The battens are nailed or screwed to wall plugs, preferably patent fibre plugs. The battens should be arranged to support all four edges of the plywood sheet, and if necessary intermediate grounds should be fixed to give support at 20-inch centres (for $\frac{3}{16}$-inch plywood). The sheets should be nailed along the edges with $\frac{3}{4}$-inch fine nails which may be concealed behind cover strips, or stopped.

Slotted Plywood.—Thin sheets of ordinary plywood can be bent to moderate curves, but where thicker material must be used or curves of short radius are desired, slotted plywood is better. This has a thick slotted core veneered on both faces. When bent it does not spring back if released but retains rigidity in the bent shape.

Built-up or Laminated Boards.—These have thick built-up or laminated cores. They are made in the following thicknesses: $\frac{1}{2}$ inch, $\frac{5}{8}$ inch, $\frac{3}{4}$ inch, $\frac{7}{8}$ inch, 1 inch. They are used in panelling and for wide surfaces without intermediate support, flush doors, and as a substitute for wide boards.

Wall-Boards for use as wall coverings will be found described in Chapter 13, Vol. III. These are finished to represent panelling, with subdivisions formed either with special strips tacked over the joints or wood mouldings cut to lengths required.

FIG. 122.—DEEP EAVES WITH MATCHBOARDED SOFFIT.

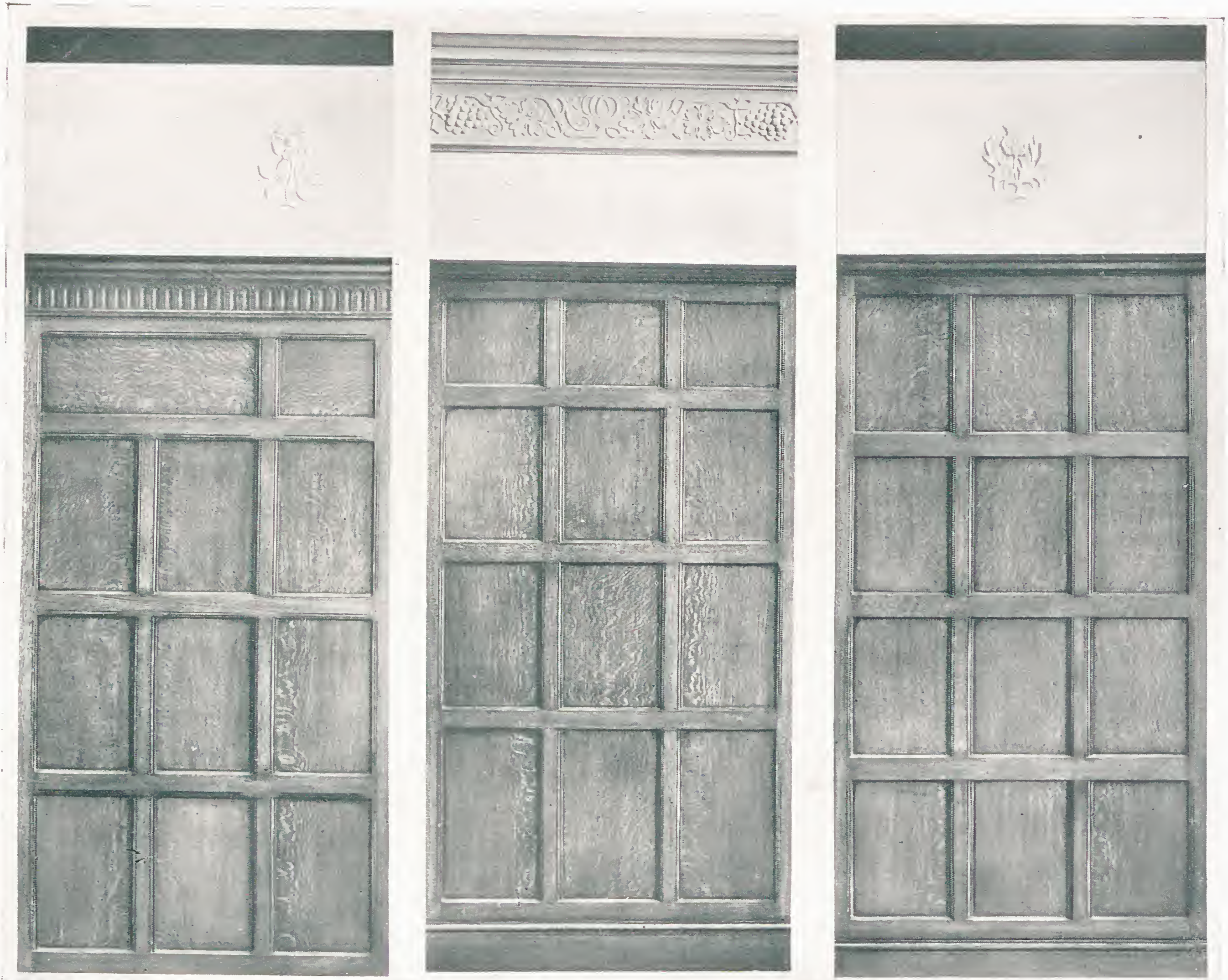


Fig. 123.—ELLIOT'S "READY-MADE" PANELLING.

CHAPTER 8

JOINERY: DOORS

DOORS are divisible into two main types: Exterior and Interior. Exterior doors are generally heavier and are designed and constructed for high resistance to the weather.

The simplest full-sized door consists of match-boarding nailed to horizontal ledges. An elaboration of this type has diagonal braces to prevent sagging and a further elaboration consists of framing along the four margins. For Exterior entrance doors and some Interior doors the panelled type is usually adopted, but the flush-surface type is increasingly used for Interior doors.

FRONT DOORS

The Front Entrance Door, though generally specially designed for the building in which it is to be fixed, and in conformity with the purposes which the building is to serve, yet there are certain principles having a more or less general application.

The following are what may be termed the basic types of doors:

The Ledged Door.—This consists of battens about $5 \times \frac{7}{8}$ inch or more according to the requirements, tongued or grooved, or rebated and with butt, feather, or V joints, or beaded, secured at the back to ledges of varying sizes from 7-inch bottom ledge, 9-inch middle or lock ledge, and 5-inch top ledge.

The ledges are sometimes fixed on the outside of the battens, in which event they should be chamfered at their top edge, and it is advisable that they should be fixed with screws. It is sometimes thought advisable that this chamfer should be worked on the bottom as well as on the top of the two upper ledges; whilst this may be a matter of opinion, there is no doubt that it is advisable to chamfer both ends of all three ledges, and for convenience in opening and shutting, the ledge should terminate at least 1 inch short of the width of the door at each side.

In *constructing* this type of door it is first necessary to obtain the exact width between the door frames in which the door is to be hung. (*Note.*—Most doors are made in modern construction of certain stock sizes, 2 feet 8 inches in width and 6 feet 8 inches in height, and the widths of the openings in the walls are constructed accordingly. The sizes are really the dimensions between the rebate abutment in the door frame; the actual door itself is made $\frac{1}{16}$ inch less in height and $\frac{1}{8}$ inch less in width. Where

this is not so the distances apart of the door frames must be adjusted to suit, or the doors will require planing and paring to fit.)

When the width of the door has been obtained, this should be divided by 5 inches into as many times as it will go. If, however, an excess is left over after this division, as for example, 2 feet 8 inches $\div 5 = \frac{32}{5} = 6\frac{2}{5}$, either the 2 inches must be divided up and added on to each 5 inches and the boards cut to this width, or alternatively 1 inch may be added to the width of the outer boards on each side of the door, which latter is the better plan.

The deciding factor in choosing whether the battens should be cut narrower and more, or wider and fewer, is the economy of the matter; but it should be remembered that in wood, the seasoning of which may be in doubt, it is preferable to use narrow widths than wide ones to avoid the likelihood of curling. Further, the main weakness of doors of this pattern is that after use they frequently twist. A way of preventing this is first to nail the ledges on to one outside batten, driving the nails in diagonally from the back, and then turning them over and punching them in below the surface, afterwards to be puttied. It is best to drive five nails to each ledge, arranged in a square pattern, with the fifth nail in the centre.

For outside work the tongues of the joints, either feather or rebate, should be painted with red lead before assembling. The remainder of the battens are then driven up tightly into position and nailed.

Screws in slots, as described in the last chapter, may be substituted for the nails, being helpful in affording possibilities of adjustment in the event of twist appearing later.

In addition to being nailed, and where the battens are thicker and therefore more liable to curl and warp, these ledges may be let into an undercut groove cut in the back of the battens, the ledges being splayed on their top and edges to fit into the undercut or dovetailed groove.

Where this type of door is used in imitation "Antique" styles, as it sometimes is for entrance doors, the battens may be from 2 inches thick from back to front. In this case it is essential that the ledges should be let into them in the manner just described.

It is also preferable, in entrance doors of this type, that the jointing between the battens should consist of hardwood feathers, which, in the event of the joint pulling apart, will stop the daylight from showing through.

Ledged and Braced Door.—Another trouble to which the last-mentioned type of door is subjected is that of sagging. This is really due to the weight of the battens on the ledges, and it may also be increased by the unequal shrinkage in length of the battens.

To overcome this diagonal braces are worked in between the ledges running upwards and outwards from the hinges, from points 3 inches from the ends of the ledges. The braces should be about 6 inches wide

Fig. 124.—INTERIOR DOOR WITH HORIZONTAL PANELS.

(Courtesy of H. Newsum, Sons & Co., Ltd.)

Fig. 125.—FLUSH DOOR WITH FIGURED VENEER.

(Courtesy of Leaderflush, Ltd.)

Fig. 126.—FLUSH DOOR WITH GLAZED PANELS.

(Courtesy of Leaderflush, Ltd.)

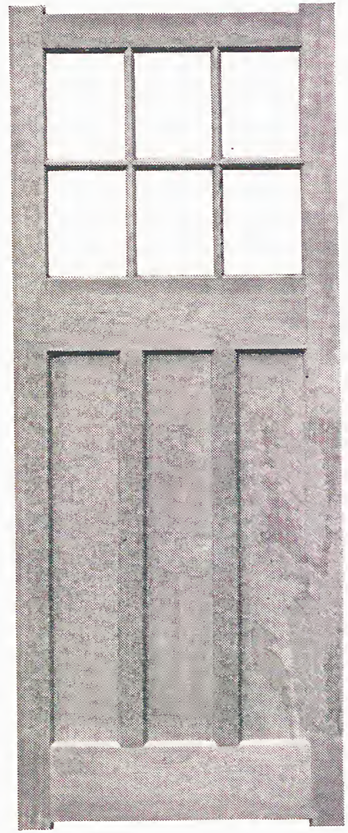


Fig. 127.—DOOR, UPPER PANEL WITH BEADED GLAZING BARS.

(Courtesy of H. Newsum, Sons & Co., Ltd.)

and housed into the ledges splay cut and with a square shoulder or abutment at least 1 inch wide. They should also be nailed as described for nailing the ledges, which is known as *Clench* nailing.

The Lock or Middle Ledge should be squared out, and may require widening in both the above types of door to carry the lock, which should be fixed on it, and must be a rim lock, *i.e.* one fixed externally and not mortised into the interior of the woodwork as in interior doors.

Note.—If the door frame is set in an outside rebate in the brickwork, with consequently a projection of brickwork inside, and the door is to be hung to open inwards, then either chases must be cut in the brickwork to accommodate the ledges and braces when the door is opened fully back, or the ledges and braces must be cut short.

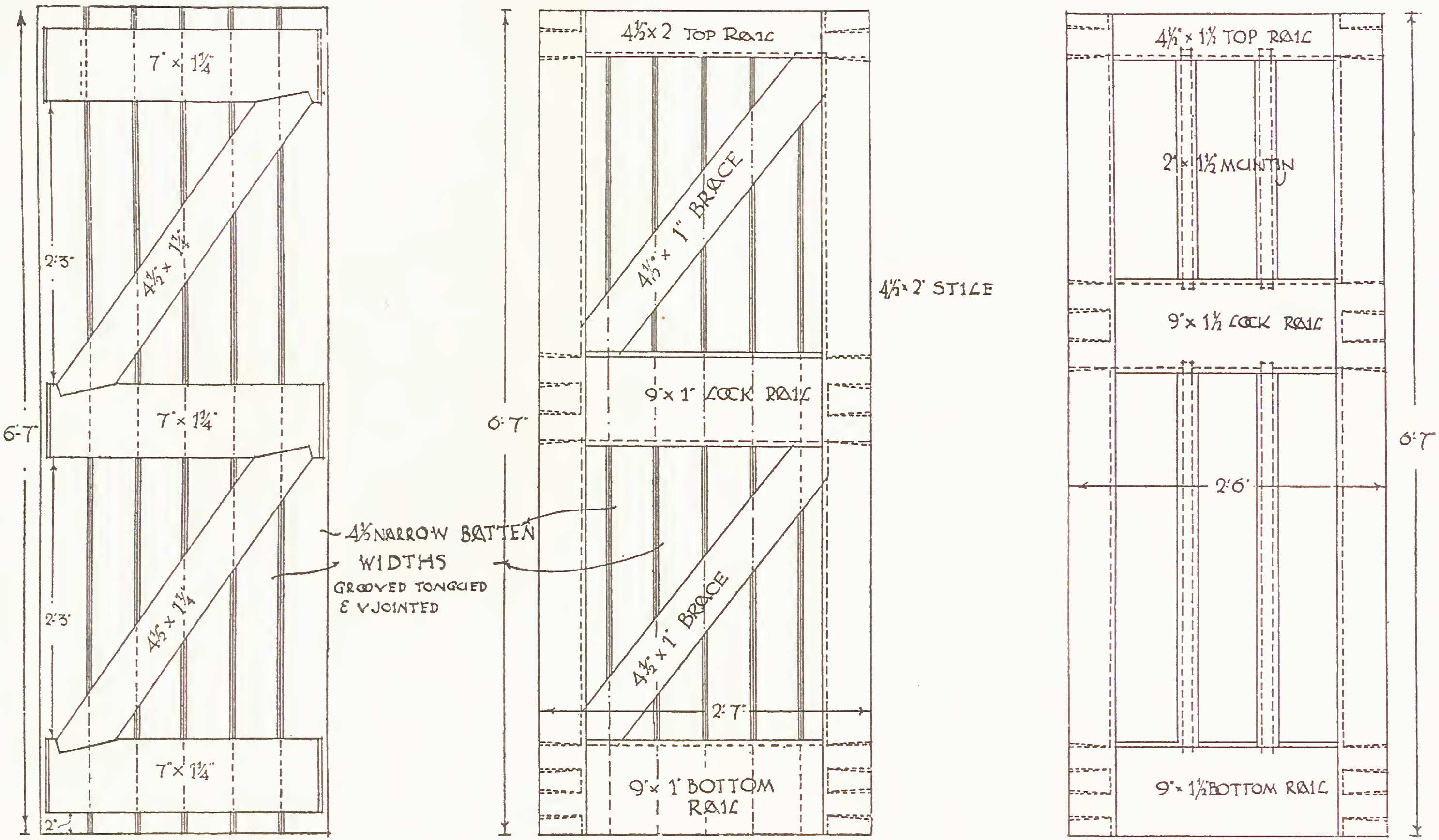
Fig. 128.—Pair of garage doors. Upper panels glazed. Lower panels matchboarded.

(*Courtesy of H. Newsum, Sons & Co., Ltd.*)

These types of doors are generally hung with T or cross garnet hinges, the upper one running across the door to a point at about its centre and the bottom one to a point two-thirds across the width of the door. Such hinges afford additional support to the door against the tendency to twist. In doors of the heavier type, when used for front entrance doors as described above, the hinges will be heavier also. These may then consist of either single-strap hinges about 2 feet in length of wrought iron punched for $\frac{5}{16}$-inch bolts, or they may be of double straps, one on the face of the door and the other on the back, and both joined together and working on a gudgeon pin screwed to the doorpost or attached to a *Raglet*, when the door is hung directly on to the brickwork or masonry without a frame.

Framed, Ledged, and Battened Doors.—In design there is an unsuitability about both the former doors, no doubt due to the indefiniteness of their endings at top and bottom, and the battens not being enclosed. To overcome this, and at the same time to lessen the likelihood of twisting and sagging, the battens are fixed into a frame consisting of a top rail and two stiles of a thickness sufficient to take the thickness of the battens plus that of the ledges.

In *construction* the top rail is first framed to one stile and then the battens are fixed on. The joint between the top rail and the stile is a



Ledged and braced door. Ledged, braced, and framed door. Six-panelled door.

Fig. 129.

haunched tenon pinned and wedged in the best workmanship. The jointing for the middle rail, or ledge, and the bottom rail is a bare-faced tenon, or two single halved tenons, one above the other, also pinned and wedged. The inner edge of the stiles and the bottom edge of the top rail are either rebated or grooved for the reception of the battens.

The width of the rails most generally adopted is 5 inches for the top rail by 2 inches thick; 9 inches for the middle rail by 1 inch thick, and 9 inches or 7 inches for the bottom rail by 1 inch thick. The bottom rail should be fixed with its lower edge at least 1 inch above the bottom of the door.

Framed, Ledged, Braced, and Battened Door.—This type of door is similar to the last described, but has in addition diagonal braces inclined upwards and outwards from the hanging stile towards the shutting stile.

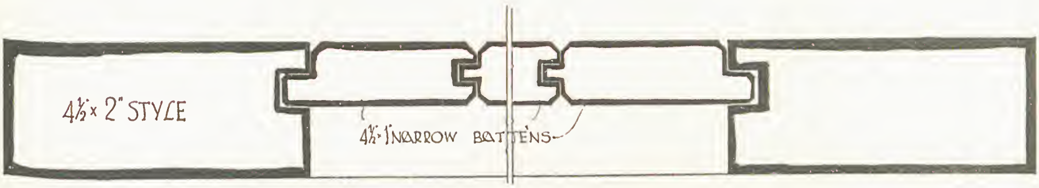


Fig. 130.—Horizontal section of ledged, framed, braced, and battened door.

These braces, however, are not required as a rule unless the door is over the usual width; and in the framed door they are let into grooves cut in the stiles at top and bottom, and at the same time into grooves cut in the rails, the ends of the braces being shouldered to fit into the right angles formed by the braces and stiles. The top rail in this type of door is generally finished $5\frac{7}{8}$ inches by $2\frac{1}{2}$ inches; the middle rail is $9 \times 1\frac{1}{2}$ inches, and the bottom rail 9 to $11 \times 1\frac{1}{2}$ inches.

When these doors, which have tenons and mortises, are put together they are glued and wedged with the ends of the tenons and wedges, and the ends, top, and bottom of the stiles left projecting to be sawn off after the door is finished.

The Cross-battened Door is a built-up door of a heavier nature than those just described, and it is used in certain styles of design for entrance doors. It consists of a frame composed of stiles, top, middle, and bottom rails, and cross braces to show on the face composed of rebated or grooved and tongued battens $5 \times \frac{3}{4}$ inch, to form triangular panels filled in with similar battens run horizontally. To form the interior face, battens of the same size and form are nailed over the whole door vertically. In the construction of this door the braces must be cut in first and nailed to the battens, the stiles being fixed on afterwards, the groove cut in them being driven on to the tongues formed on the rails.

DOOR FRAMES—EXTERIOR

Exterior door frames are usually called solid frames, and unless for exceptionally heavy doors they are cut out of $4\frac{1}{2} \times 3$-inch deal, rebated to provide the door with a shutting edge. Otherwise they may be either left with square arrises or chamfered or moulded. They consist of two upright door *Posts* crossed at the top by a door *Head*.

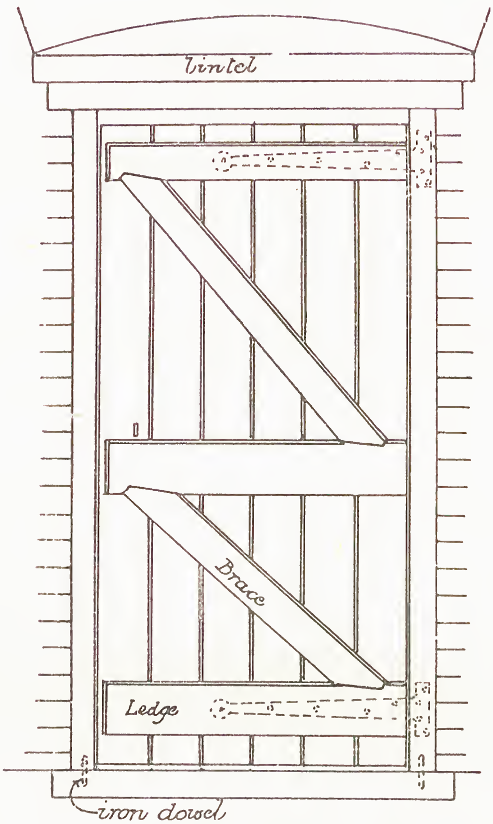


Fig. 131.—Detail showing door hung.

The heads are jointed to the posts either by means of a haunched mortise and tenon, or by means of a slot or open mortise and tenon. In the latter case the tenon is pinned with a $\frac{3}{4}$-inch hardwood pin. As entrance doors invariably open inwards the rebates are cut on the interiors of the door frames.

Alternatively a better method of jointing the heads and posts is to form a double mortise and tenon, having any splay or moulding on the interior or exterior arris mitred at the junction. The tenons should be wedged with hardwood wedges.

In all these forms of door frames the head is projected beyond the door posts to be built into the abutment or jamb of the masonry.

The width of the opening of door frames depends upon the purpose for which the doors are to be used: for front entrance doors the width in the clear should be at least 3 feet; back entrance doors may be 2 feet 10 inches to 2 feet 8 inches; whilst outside W.C.s and outhouses may have the openings between the frames only 2 feet 5 inches to take a 2 foot 6-inch door. The heights of all doors, unless of special design, being 6 feet 8 inches, the height of the underside of the frame should be 6 feet $7\frac{1}{2}$ inches.

The Foot of the Door Post, which generally rests on a stone sill, should be fixed thereto by means of a $\frac{1}{2}$-inch round iron dowel 4 inches long and be rested on a lead pad to act as a dampcourse.

Fixing the Frame.—The frame is also fixed to the brickwork by being nailed to wood pallets or breeze bricks already described; and it may be either built in as the work of building the walls proceeds, or cut away for and fixed after the roof is on. The latter is the better method as it

prevents damage being done to the door frames during the passage of heavy building materials. The joints are then raked out at 2-foot 6-inch heights and plugged with wood plugs cut off just so as to allow sufficient space for a tight fit. The frame is bedded on a layer of putty and spiked for nails being driven at an angle.

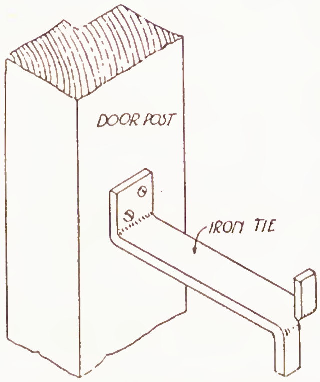


Fig. 132.—Wall tie to frame.

The building-in method is adopted in cheaper-class work where speed is essential, but as the timber is probably poorly seasoned, and as there is also a good deal of moisture in the masonry, this practice is liable to originate decay. As it is difficult, where the frame is built in as the work proceeds, to bed it in hair mortar or putty, the faces coming against the brickwork should be either given a coat of boiled linseed oil or at least painted in red-lead paint.

To carry heavy front entrance doors the frames may be required to be heavier, up to 6 × 4½ inches, but above those dimensions they are generally boxed out, as greater widths are usually for appearance rather than called for by the actual strength requirements.

Where the frames are moulded on the arrises, as in the Gothic and Classic styles, the mouldings will be finished at the base by being either scribed or worked out on to a chamfered plinth block. The interior jamb will be finished with a lining, as is to be described for interior doors, the solid ground being grooved to take a rebate cut on the lining or casing.

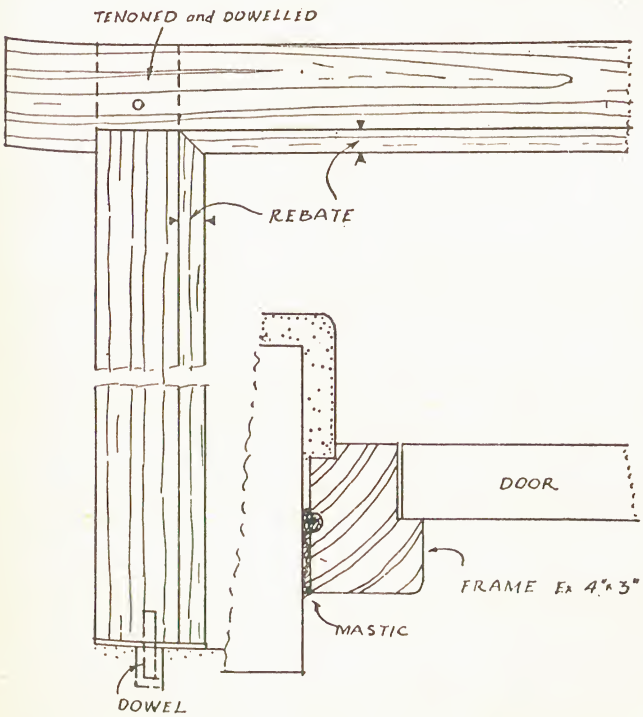


Fig. 133.—Frame for external door. The bituminous mastic between frame and wall jamb makes a watertight joint.

Segment-headed Frames.—Where an arched head is required to an entrance door, this is cut out of the solid, provided the rise of the arch is not too great. Above the width of ordinary deals the head must be built up as for a semicircular head.

The segment-headed frame should have the head run beyond the post

to form *horns* for building in at least 6 inches long, but where the conditions are such that the horns cannot be built in, the mortise and tenon joint between the post and head should be haunched. The horns are horizontal, and any chamfering or moulding on the inner arris of the frame will be continued on the corresponding arris on the head.

The Built-up Head, as used for arches, the rise of which is too great to permit of the head being cut from the solid, is formed of at least three lengths, and in double-thickness breaking joints, and glued and screwed together. The head is jointed to the posts by a hammer-head tenon, as already described, cut on the top of the post. And where there is a transom, which forms a square head for the door, this must be double tenoned into the post under the hammer-head tenon. The semicircular opening above the door is then filled in with a transom light, or as it is more usually termed a *fanlight.*

Fanlights, which may be segmental or rectangular, the latter type being more usual, are fitted with hinged casement sash generally hinged to the transom on the interior at the bottom and hung to fall inwards from the top. Transoms in casement windows, as will be explained later, are generally hung from the top to lift open in an outward direction.

The head of the door is then rebated above for the reception of the transom light, and the rebate on the outside of the horizontal head or transom should be weathered.

Stays.—Door frames should be sent to the job braced with temporary stays, one across the bottom, and one corner-wise across the angle at the top of the opening. These assist the frame to keep the required width and shape, and are especially necessary when the frames are built in as the work proceeds.

Vestibule Framings, though actually door frames, are constructed in a manner resembling casement-window construction, with the difference that the dimensions of the frame are larger. They are generally fitted with a transom, which is run right across the framing at the height of the door head, and the part above is fitted with transom lights either hinged to open or fixed.

At the sides of the door the spaces may be filled in with frames either glazed or panelled.

The transom is run across the posts which are in separate sections above, and is jointed behind a lining run up the face of the posts by means of a dovetail tenon properly wedged at the top with folding wedges, as was described in the description of joints.

Entrance Doors to Offices, Banks, etc., contrary to the usual practice and where sufficiently recessed from the building line, are hung to open outwards to fit back into a recess at the side of the recessed entrance. This is done where it is required to have the outside entrance doors permanently open during the day and closed only at night, the vestibule doors being of another pattern, which will close automatically, such as swing doors or some form of circular door.

The frames of such external entrance doors, which are sometimes termed *Warehouse Hung* doors, must be of sufficient width to enable a deep rebate to be cut on the inner face of the hanging stile in order that the door, hinged on the outer corner of this, may fold back on to the frame.

The lobby interior is generally panelled to match the style of the door

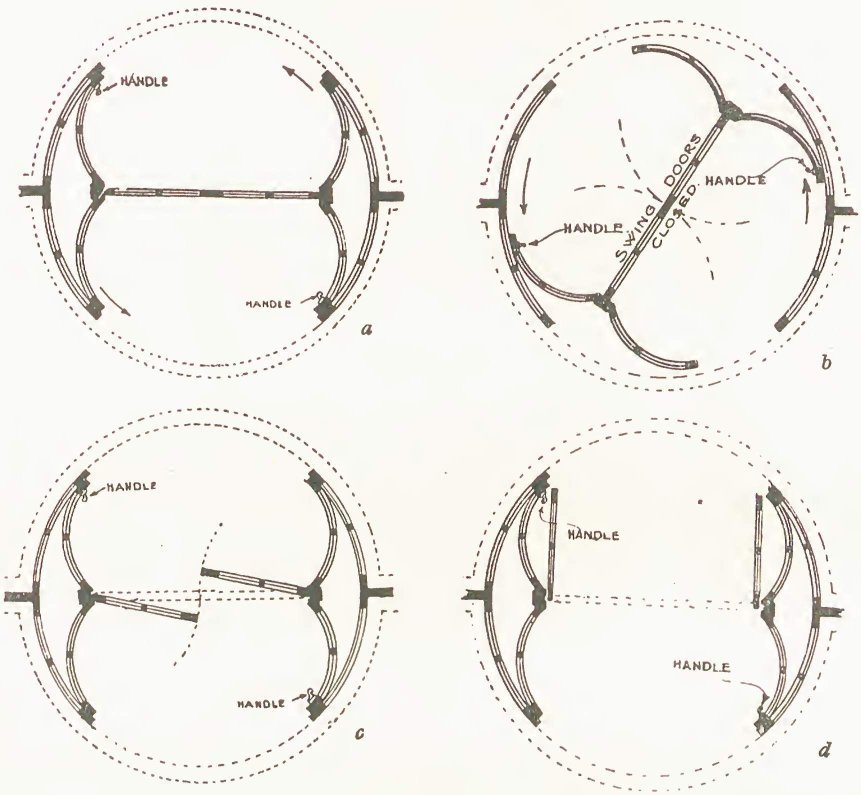


Fig. 134.—Revolving door. (*a*) Ready for use. (*b*) Revolving. (*c*) In use as swing doors. (*d*) Fixed open.

and the panel framing is rebated into the solid door frame, so that when the door is folded back in its open position it matches the panelling on the other side of the lobby facing it.

Revolving Doors are now fitted to office and other public buildings, such as hotels, where there is constant foot traffic in and out, and it is desirable to exclude draughts. These have the effect of keeping the opening closed except when actually in use, and are superior to two-way swing doors, in that they afford entrance at one side and exit at the other, *i.e.* in the direction of the revolution of the door. This is centrally pivoted, and revolves from right to left, so that passage through should always be made on the right-hand side.

The door itself consists of four leaves which are so made that they can, if required, be folded back into the circular glazed framing which surrounds

them. They can also be so folded back into the surround that two leaves are then usable as double swing doors working on double-way hinges.

PANELLED DOORS

Panelled doors, both for exterior and interior use, are made upon the same principle, which consists basically, whatever the design, of a frame jointed together with some form of mortise and tenon and the spaces between filled in with panels of either wood or glass. In front entrance doors the upper portion is frequently glazed, and the panel is then fitted with glazing bars.

The inner edges of the framework are grooved with a $\frac{3}{8}$-inch deep groove to take the edges of the panels; and this framework consists of two upright *stiles*, one at each side, and generally three (though there may be more in certain special types) rails, *i.e.* top rail, middle or lock rail, and bottom rail.

Dimensions.—The width of the door is that required to fit the opening, a usual stock size being 2 feet 8 inches and the height 6 feet 8 inches. The stiles are $4\frac{1}{2}$ inches wide and of the thickness specified for the door, which may be from $1\frac{1}{2}$ inches in cheap work to $2\frac{1}{2}$ inches in the best style of workmanship. The usual thickness for ordinary doors in average-class work is 2 inches, though for front entrance doors this may be more, depending upon the design.

As so much joinery is machine-made in modern work, the following stock sizes are given:

Exterior Doors with glazed upper panel:
- 6 feet 6 inches × 2 feet 8 inches × 2 inches
- 6 feet 10 inches × 2 feet 10 inches × 2 inches
- 7 feet × 3 feet × 2 inches

Glazed Doors, double:
- 6 feet 8 inches × 3 feet 8 inches × 2 inches
- 6 feet 10 inches × 3 feet 10 inches × 2 inches
- 7 feet × 3 feet 6 inches × 2 inches
- 7 feet × 4 feet × 2 inches

Glazed Doors, Single moulded on one side:
- 6 feet 4 inches × 2 feet 4 inches × $1\frac{1}{2}$ inches
- 6 feet 6 inches × 2 feet 6 inches × $1\frac{1}{2}$ inches
- 6 feet 6 inches × 2 feet 6 inches × 2 inches
- 6 feet 8 inches × 2 feet 8 inches × 2 inches

Panelled Doors, Solid Ovolo moulded, 3–9 panels:
- 6 feet × 2 feet × $1\frac{1}{4}$ inches
- 6 feet 4 inches × 2 feet 4 inches × $1\frac{1}{4}$ inches
- 6 feet 6 inches × 2 feet 6 inches × $1\frac{1}{4}$ inches
- 6 feet 4 inches × 2 feet 4 inches × $1\frac{1}{2}$ inches
- 6 feet 6 inches × 2 feet 6 inches × $1\frac{1}{2}$ inches
- 6 feet 6 inches × 2 feet 6 inches × 2 inches
- 6 feet 8 inches × 2 feet 8 inches × 2 inches

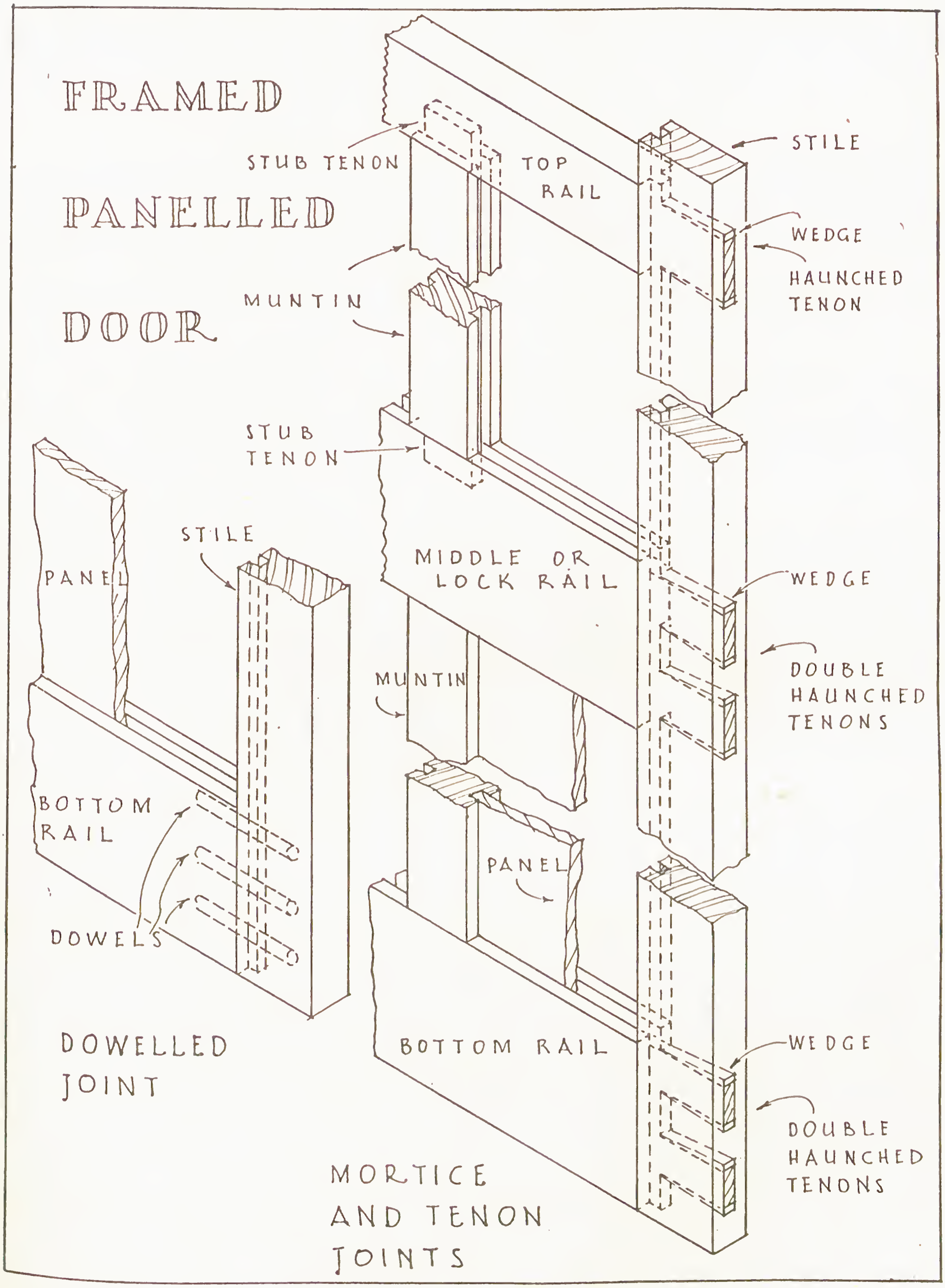


Fig. 135.—Isometric drawing of typical door joints. The dowelled joint is used in machine-made doors.

Panelled Doors, Single Panel:
- 6 feet × 2 feet × $1\frac{1}{2}$ inches
- 6 feet 4 inches × 2 feet 4 inches × $1\frac{1}{2}$ inches
- 6 feet 6 inches × 2 feet 6 inches × $1\frac{1}{2}$ inches
- 6 feet 6 inches × 2 feet 6 inches × 2 inches
- 6 feet 8 inches × 2 feet 8 inches × 2 inches

Garage Doors:
- Solid and Upper panel, 7 feet × 7 feet × 2 inches
- Glazed, 7 feet × 7 feet 6 inches × 2 inches
- In pairs, 7 feet × 8 feet × 2 inches
- Ledged and Braced, 8 feet × 8 feet × 2 inches

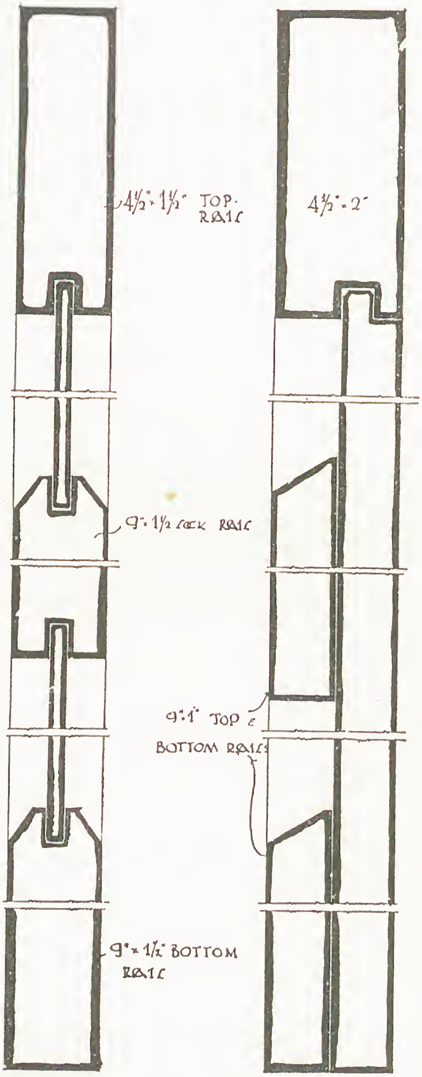


Fig. 136.—Vertical sections of a panelled, and a ledged, braced, and framed door.

The Construction of the Panelled Door is as follows:

The top rail is cut with a haunched tenon at each end and fitted into the stiles, which are left with extensions, beyond the finished height of the door, which are called *Horns*. These, and all the other tenons, are wedged with two wood wedges driven in from the outside of the stiles.

The bottom and middle rails are jointed to the stiles with double-haunched tenons; but with the exception that, where the middle rail is to receive a mortise lock, the tenon is alternatively a bare-faced tenon or double tenons, which last are used in thick doors.

In the four-panel door there is a central upright to the framework termed a *Muntin*, which is usually 4 inches wide. This is stub-tenoned and mortised into the rails, being in short lengths and discontinued at the rails.

Along the inner edge of all the stiles, rails, and muntins, there is run a $\frac{5}{8} \times \frac{3}{8}$-inch groove for $\frac{5}{8}$-inch panels to fit into.

Thus it will be seen that the principle underlying the framing of doors is that the stiles should be continuous and run through the rails, but that the rails should be run through the muntins.

The description given above provides a four-panel door, and the principles are the same, however many panels there may be, except, of course, for a one-panel door, in which there is no middle rail or muntin,

but the framing is otherwise the same. It is not usual to make a door with more than nine panels, except for very special positions such as a West door in a church; St. Pancras Church, in London, for example.

In the ordinary four-panel door the guiding factor as to the height of the lock or middle rail is that it should be a convenient height for the hand to grasp the handle in opening the door. If this is made about 3 feet 6 inches to the top of the rail, it will be found generally satisfactory. At one time three-panel doors, having two long upright panels and one horizontal across the top, were fashionable and were common, until a very general dissatisfaction made itself felt at the fact that as children could not reach the door handles, they had to be let in and out of a room, which was not conducive to a state of restfulness. In this matter of convenience the width of a door is an important point as, though furniture is made much lighter to-day than some years ago, there is not, nor can there be, much reduction in the size of an armchair, and even if this is turned on its side, if one doorpost is against a side wall, as it often is, there will be considerable difficulty in getting it through any opening less than 2 feet 6 inches wide.

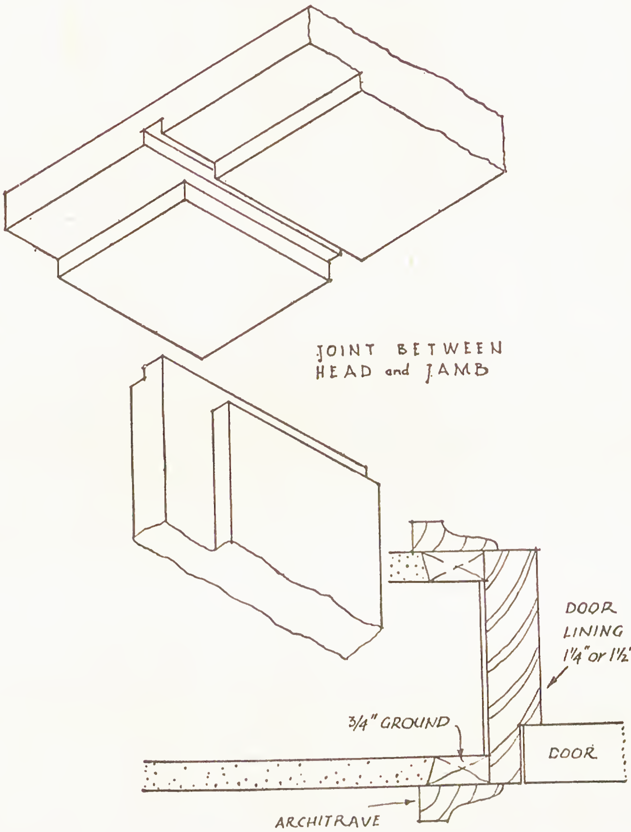


Fig. 137.—Doorway lining and architrave.

Linings and Finishings.—The *Interior* doors to all the rooms of a building except cellars, sculleries, and such type of working space, are fitted into a rebated board, generally $1\frac{1}{2}$ inches thick in its thickest portion, and of a width necessary to cover the depth of the opening, *i.e.* the thickness of the wall or partition through which the opening is cut. This is termed the *Lining*.

In its simplest form the lining is $10\frac{1}{2}$ inches wide for an opening in a 9-inch wall and rebated at both sides, one being to form a closing abutment or shoulder for the door to shut against and the other for decorative effect to match.

The linings are continued over the top of the doors, when they are termed *Soffit Linings*, and are of the same dimensions. A tongue is formed on the top of the jamb linings to fit into a groove cut in the soffit lining.

In cheaper work the rebate is formed by nailing a ½-inch-thick board on to the face of a 1-inch board of the full width required. But as this with poorly seasoned wood is liable to strip curling, a better job is effected by rebating a solid 1½-inch board in the manner described.

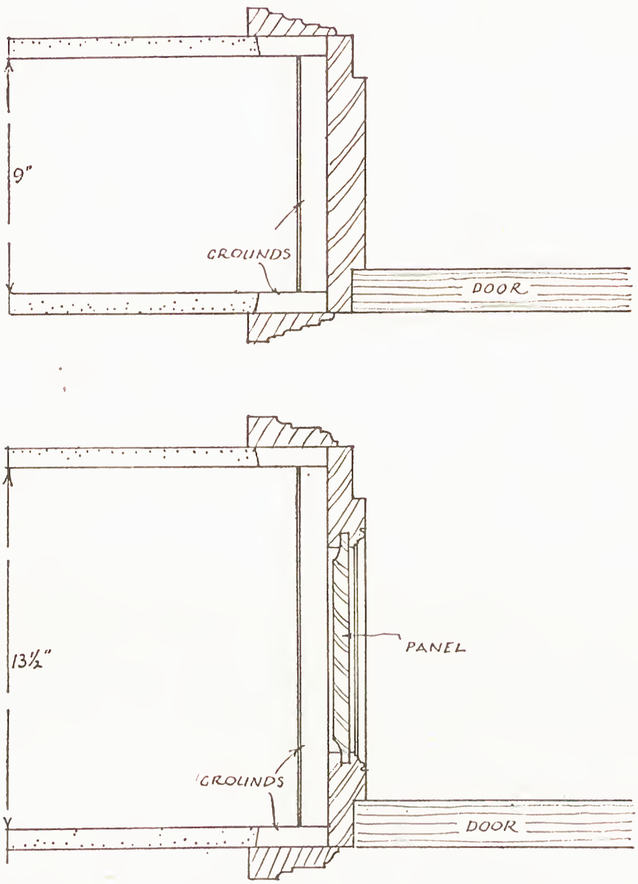


Fig. 138.—Jamb linings to interior doorways. (*Top*) Lining fixed to wood ground. (*Bottom*) Panelled lining to deep jamb.

Panelled Linings.—In more decorative work the linings are often panelled to match the panelling to the door, when the rails and details of the mouldings correspond. These panelled linings are built up, in a similar manner, of two rebated stiles with a bottom rail of the same height as the bottom rail of the door, and rebated or grooved on their inner edge to receive the tongue cut on the panel edge. An alternative method is to form this rebated stile of two pieces of wood, one the rebate which is tongued into the other—the stop—the panel being tongued into the opposite face of the stop.

Grounds are rough wood framings fixed round and through the openings in the brickwork to afford a fixing for the linings. The grounds themselves are nailed to wood pallets, plugs, or breeze bricks, and consist of cross pieces 2 × 1 inch run through the opening and termed *Backings*, dovetail tenoned into vertical strips 3 × ¾ inch, fixed flush with the plaster face of the wall, and termed *rough grounds*. These rough grounds are generally undercut or splayed on their outer edges to afford a key for the edge of the plaster. The grounds should be framed before being fixed, and be tenoned at the

corners, the soffit ground being formed in the same manner in this case, though where there is a wood lintol over the opening there is no real need for grounds, as the lining may be fixed to this. Into the bottom of the rough ground at its outer edge two rough grounds for skirtings are dovetail halved into the door rough grounds.

Over the edge of the linings, and on the face of the rough grounds, and continued about 1 inch over the plaster, the architraves are nailed round the opening. These may consist simply of splayed boards from 3×1 inch upwards in width, or they may be moulded. More elaborate architraves are framed. When the last type is used a double-framed ground is required, known as a *Skeleton Ground*, the members of this being mortised and tenoned together. Specially elaborate architraves are fixed by slotted screws, screwed into the grounds with about $\frac{1}{4}$ inch of the head left projecting. A special form of mitred tenon, used also in picture frames, is also employed for jointing the corners of these architraves. Alternative methods of jointing these mitres is to use feathers or hardwood keys as has been explained in the description of angle joints. The skeleton framed ground consists of two $2\frac{1}{2} \times 1$-inch uprights braced apart horizontally, three cross rails on each side in the height. Generally the bottom rail is of stouter material.

A Plinth or Plinth Block is sometimes placed at the foot of architraves when moulded to stop the moulding, and at the same time to afford a good finish to the skirting when moulded. The joint between these blocks and the architrave is a dovetailed feather—the dovetail mortise being cut in the top edge of the plinth block.

FLUSH DOORS

Flush-surface doors are now widely used in all kinds of buildings. They are easily cleaned and polished as there are no recesses or other lodgements for dust and with good-quality veneers an interesting decorative effect is obtained by polishing or staining. The flush surface also accords with the simple shapes and plainness of modern architecture.

Flush doors are factory produced by machine methods. They consist essentially of an interior framing or core, plywood faced both sides, with solid edging.

The construction differs slightly with various makes, and there are usually three grades or qualities. Fig. 139 illustrates three types of one make (the Leaderflush). Type A is a medium-priced door, extensively used in blocks of flats, large houses, etc. Type B is a solid laminated and veneered door of high quality, suitable for public buildings, hotels, hospitals, cinemas, etc. Type C is a cheap but reliable door for housing schemes, etc.

The construction of flush doors differs from that of traditional doors as the framing or core is entirely concealed and serves a structural purpose only. The workshops in which flush doors are produced are set

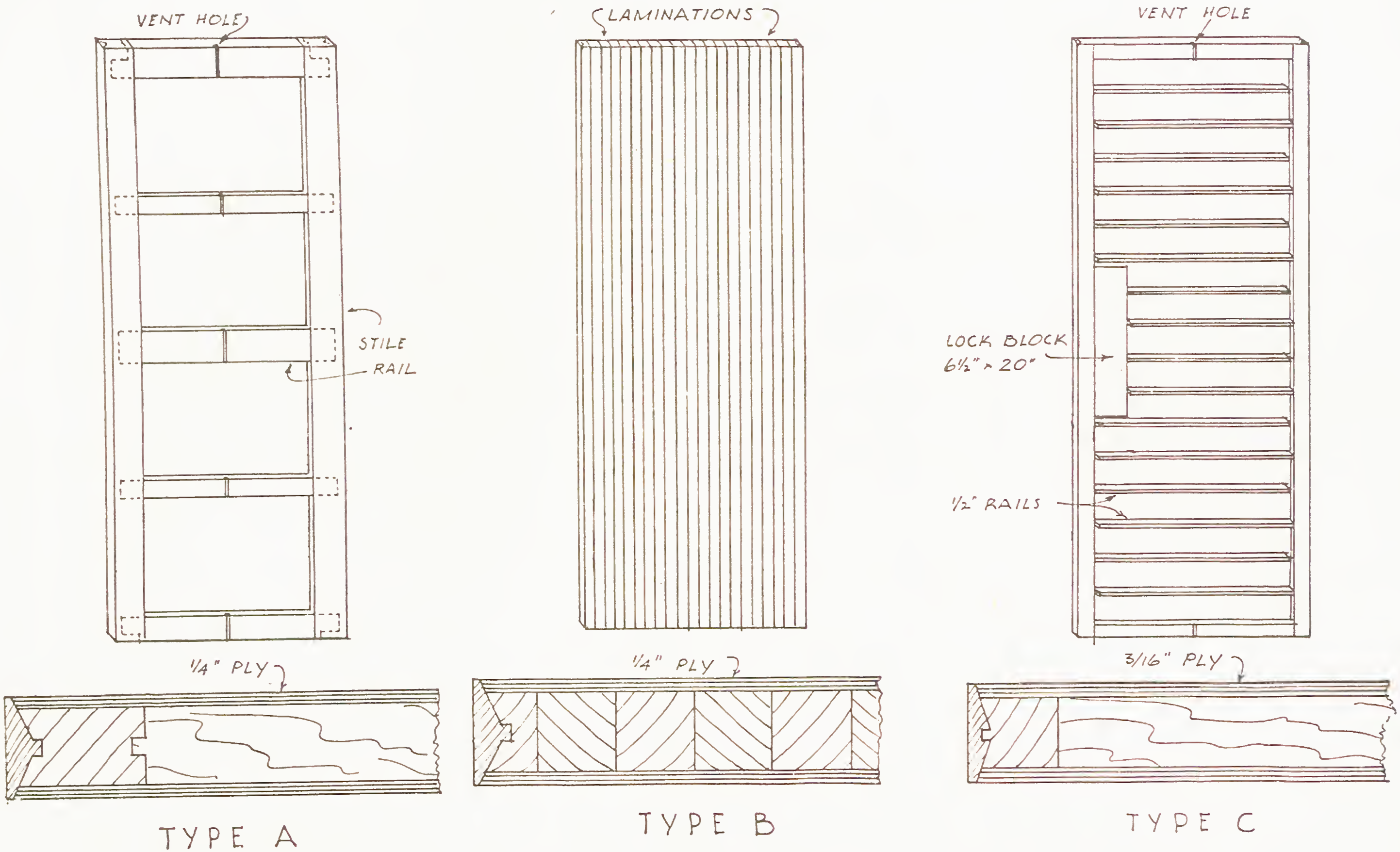


Fig. 139.—Details of Leaderflush doors.

up for large-scale production. Accurate machining is necessary and the manufacture must be carefully controlled. The panels, usually of $\frac{1}{4}$-inch plywood, are secured to the frame or core by gluing and are then subjected to high pressure for several hours.

The cheaper flush doors are stocked in the following woods: alder, birch, and beech for painting; Columbian pine for staining and polishing. The more costly doors are made with both softwood and hardwood veneers.

FITTINGS AND FURNITURE

Hinges.—Doors are hung to their frames with three hinges, usually specified as "$1\frac{1}{2}$ pairs of butts and screws." The method is to sink the hinges into both door and frame, and on the correctness of this work depends the satisfactory swing of the door. A properly hung door should stay in any position in which it is left. In fixing the hinges they are screwed to the door first, the top hinge being just below the top rail and the bottom hinge just above the bottom rail; and the pin of the hinge should stand away $\frac{7}{16}$ inch from the door line.

In marking the portion to be cut away for sinking the hinges, the door should be laid on its shutting stile with the hanging stile uppermost, and the gauge is set to the thickness of one leaf of the hinge, less half the clearance of the joint. But before actually cutting out the sinking with the chisel it is best to test the frame or lining with the plumb line, as if this is out of the perpendicular, one or the other of the hinges must be sunk farther into the woodwork, otherwise the door when hung will have a tendency to swing in one direction or the other. Thus, if the door frame leans into the room, the hinge at the top must be sunk deeper than those below it, and the middle hinge a little less than the top hinge, but more than the bottom. If the door is required to open right back flush with the wall in which it is fixed, the pin of the hinges must be given a clearance of the architrave. Special hinges known as *Parliament Hinges* are used for this purpose where the clearance required is considerable.

The width of the leaves of the hinges may be marked on the edge of the hanging stile by laying the hinge in position and scribing round it. The marked portion is then pared out with the chisel, the marked lines of the edges being cut first, and great care being exercised in not cutting too deeply, as it is easy enough to take off a little more if the door will not close, but a tedious and rarely quite satisfactory job packing out a hinge which has been sunk too deeply.

When the three hinges are on, the door is raised and stood against the hanging rebate of the frame or lining, packed up on wedges to give a clearance for the carpet at the bottom and just clearance for closing at the top. The hinges are then opened out and their cutting lines marked on the rebate of the frame or lining, and cut in the same way. Then one screw to each hinge is screwed in and the wedges removed for testing the door. The screws must be driven in at right angles to the surface or their

heads will not lie flat, the result being that the door will not shut. Another cause of a door refusing to shut is that either the tenon or the wedges in the tenons have not been cut off flush with the edge of the hanging stile.

Where a very thick carpet is required hinges are used known as *Rising Butts* which, being made with helical joints, or joints at an inclined plane, cause the door to rise in its swing open.

A great time-saving is effected by using *Pin Hinges* where a door is required to be removed from its hinges, the loose pin lifting out readily.

Doors which it is required to open both ways and to swing to automatically in such positions as between kitchen and service pantries are fitted with special-made hinges, the most usual of which is the *Helical Hinge*, which consists of three flaps, and has springs within the pin barrels. At the top of the barrels are small circular holes for a steel pin to be inserted for regulating the springs. One spring hinge is sufficient for a door, and this is generally placed at the top, the others being without springs. To fix the hinge the springs must be released. For heavier doors, such as entrance doors, a special spring is provided for fixing in the floor working in conjunction with a shoe which carries the bottom rail at its heel.

Back Flap Hinges are used for fixing to the face of the lining instead of the edge, and have wider leaves.

Locks.—Since there have been doors to buildings it has been customary to furnish them with some form of lock. In its earliest form the lock was no doubt a seal, which must not be broken without the owner's permission, but to-day, though the variety of locks would seem to be endless, nearly all the best locks used are modelled either on the Chubb lock of 1818, or the Yale lock of 1848.

Locks are divisible into the following three groups:

Mortise Locks, which are let into a mortise cut in the stile of the door.

Rim Locks, which are planted on the face of the door and screwed thereto.

Flush Locks, which are recessed into the door from one side.

These may be either dead locks, two-bolt locks, night latches, or locking latches.

The Dead Lock is one which has only one bolt, and requires a key for use.

The Two-bolt Lock has one bolt turned by the key and a spring-latch bolt turned by a handle or door knob.

In the Night Latch the key operates from the outside and a knob from inside.

Locking Latches are those in which, when the key is turned, the door is locked and cannot be opened by the handle.

The subject of keys used with locks is one of great interest, mainly on account of their infinite variety, but unfortunately this hardly comes within the scope of the present work. However, as the joiner is often required to ease a lock, some slight account of the mechanism may be helpful.

The Bolt is the projecting tongue to be seen when a lock is fitted. This

is operated by the key or handle—the key either fitting over a pin attached to a lever or being guided by semicircular rims known as *Wards*. Either the bolt shoots backwards and forwards only when worked by the key, or it is fitted with a spring which shoots it out, the key being necessary only to withdraw it. The first is called a *Dead Bolt* and the latter a *Spring Bolt*. The action of the bolt is controlled by levers, which are perforated flat pieces of metal having gratings which must all be in the required position before the bolt can slide.

The wards and the spring are the most likely parts to need attention, and this generally consists only in oiling, though the spring may break and require renewing. In order to get at the mechanism the cover must be removed. This is done by prising out the lugs which will be found fitted in the slots, and then prising up the box cover with a screwdriver. If the spring is broken this can be knocked out with the screwdriver and hammer, and a new one inserted. If the key spindle, *i.e.* the pin over which the key fits, is bent, it may be tapped back to the correct position, but this requires doing gently.

To remove a mortise lock the door handles must first be withdrawn by unscrewing the pin at one handle and then removing the screws which hold the brass plate, the only visible part of this lock when in position. When the lock is withdrawn from the mortise the screw or screws at one side of the cover must be removed, when the cover plate may be prised off with the screwdriver. Though the interior mechanism is more intricate, the principles on which it works are the same, and it will generally be found to be the spring which is the cause of the trouble, as this is subject to rust if not oiled. The bolt also wears thin, when either a new bolt or a new plate through which it works is the remedy.

In Fixing the Rim Lock all that is required to be done is to screw it to the lock rail through the holes prepared for that purpose; and then to fix the receiver for the bolt to work into on the door frame.

Fixing the Mortise Lock.—This is performed first by laying the lock along the side of the stile in the position in which it is to be fixed and marking round its outline and the position of the spindle hole for the handles and the keyhole. Then bore with the brace and bit several holes through the edge of the stile into which the lock is to be slipped, and remove the wood with a mortise lock chisel until the lock will enter; mark round the plate. A sinking is then chiselled to receive the plate. The lock is then removed again and the position for the keyhole and spindle hole tested, marked, and then bored. The striking plate is then let into a chase cut in the door frame or lining. The end of the lock will be found to be fitted with two plates, a back plate and a face plate. The face plate must be unscrewed before the back plate is screwed into the door, and then screwed into position again.

Upright Mortise Lock.—For doors having narrow stiles the mortise lock is formed with its length in the height, and the keyhole in this lock is situated under the handle spindle hole.

Entrance Doors require a night latch to the lock in addition. This consists of a spring latch withdrawn by a knob to be worked sideways in a horizontal direction from within, working in a locking slide. These latches are screwed to the surface of the door, and the bolt works into a box screwed to the face of the door frame.

The Yale Locks are fitted as night latches to the interior of entrance doors, the outside having an escutcheon plate with a keyhole in it. A hole for this must be bored through the door from front to back.

Padlocks are required for outbuildings, and are especially suitable for garage doors. In order to render these secure, the bar of the padlock should be fitted to the bolted door and the staple on to the door which opens first. This prevents the doors from being broken open by the unscrewing of the staple. A special provision is made against this in the form of a pad bar having fixing plates recessed into the door and the screw heads covered by the bar. A more expensive form, but still more secure against forcing, is a bar which can itself be locked. With this there is no separate padlock, and it can be locked in the open position as well as when closed.

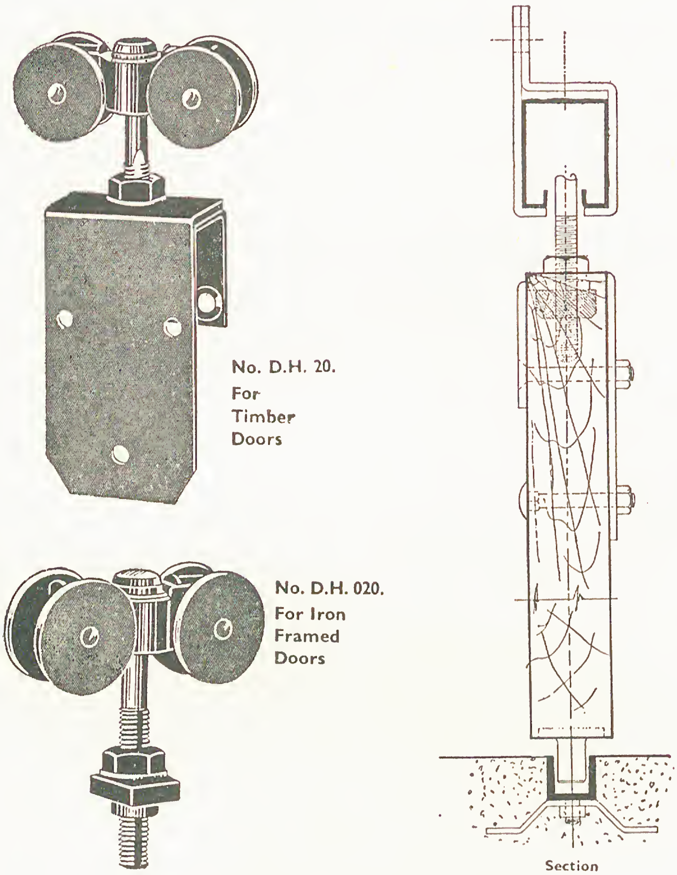


Fig. 140.—Sliding-door gear. Top-hung type.
(*Courtesy of Young & Marten, Ltd.*)

Norfolk or Thumb Latch.—Ledged and braced doors being too thin to allow of mortise locks being used and a rim lock being unsuitable for outdoor use, they are fitted with latches having an up-and-down lever action, known as Norfolk latches.

This type of latch is fitted to the inside of the door and consists of a lever working on a pin at one end by means of a *lift* raised on the inside by pressing a *sneck* or thumb plate on the inside, the extent of the up-and-

down motion being checked by a keeper fixed to the door near its edge. The end of the lever fits into a stop catch, which is curved in such a manner as to cause the lever to be raised and to fall into the catch slot

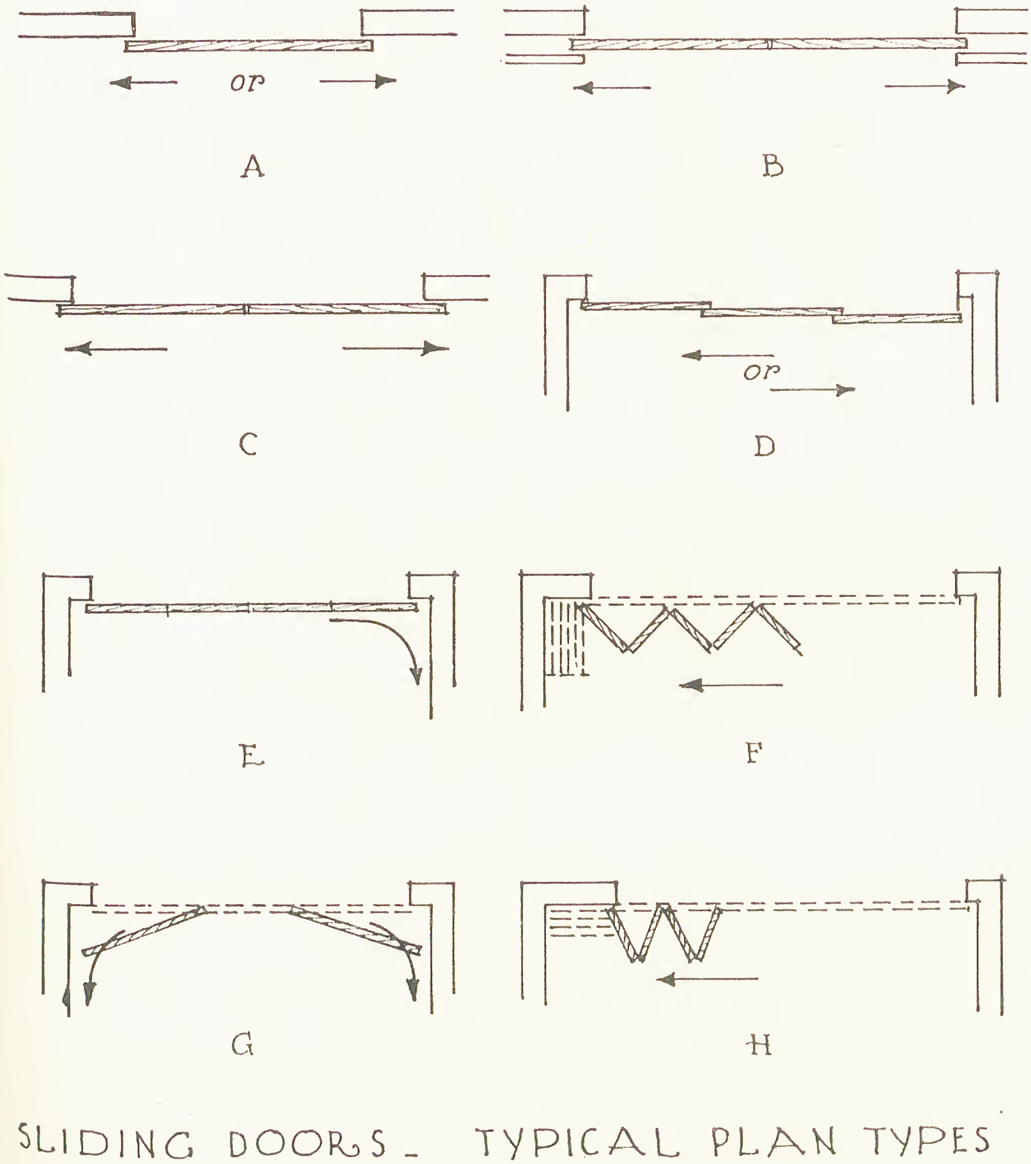


Fig. 141.—These plans show that there are sliding or sliding and folding doors to suit every situation met with in practice.

when the door is closed. On the outside the thumb latch is fitted with a back plate and handle screwed to the face of the door.

Finger Plates are not so much used now as formerly. When used it is customary to fix them both above and below the door handle on both

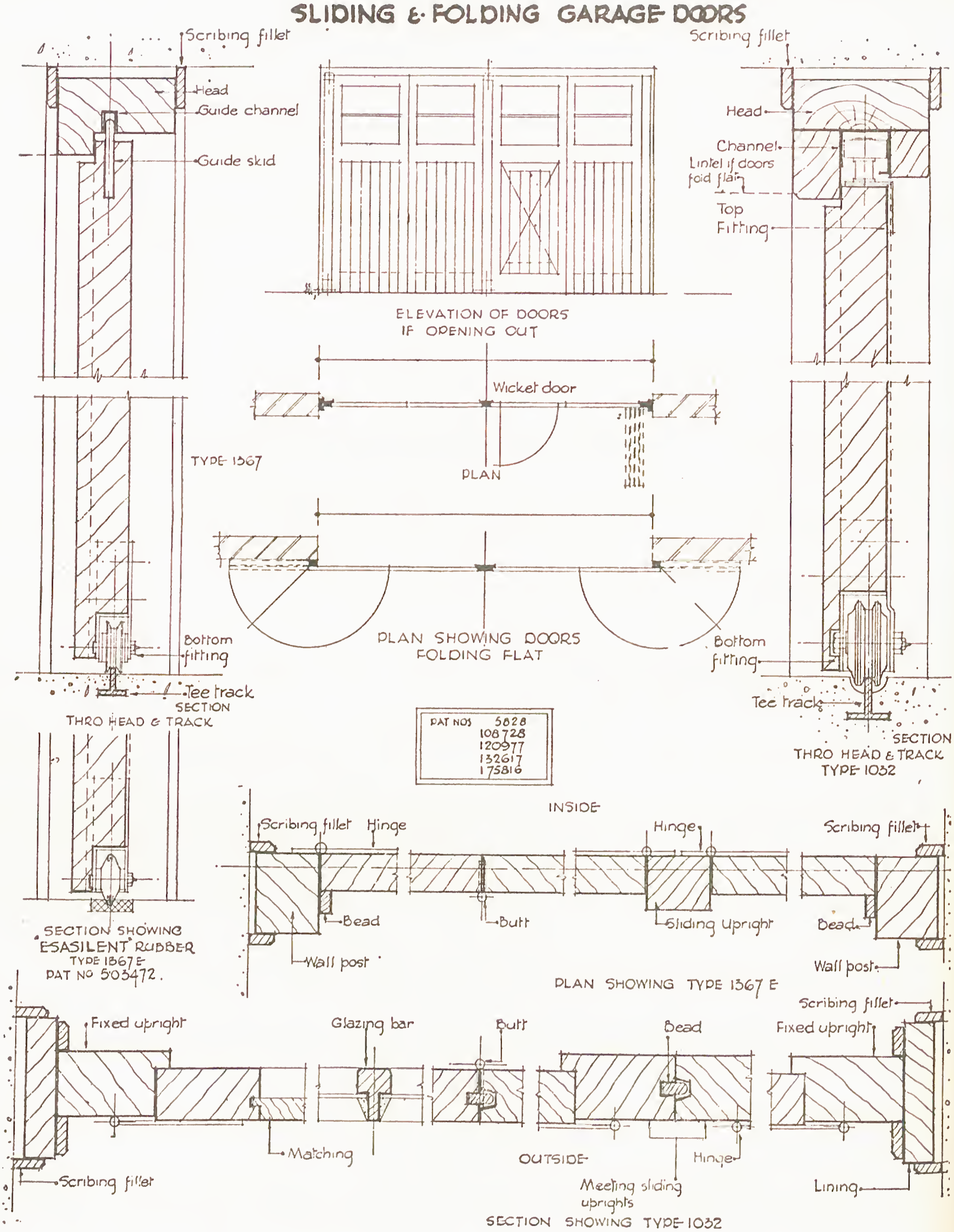


Fig. 142—Esavian medium and light sliding and folding doors for garages. Bottom-roller type. (*Courtesy of Esavian Doors.*)

sides of the door. They are made of metal, glazed earthenware, or glass, and are to be obtained in a variety of designs. The most useful adaptation of a finger plate is a transformation into a door handle, which enables a door to be pulled open.

Door Stops.—To prevent a door from injuring furniture, or a wall, a button, generally covered with rubber, is screwed into the floor or into the face of the skirting. These are known as door stops. It is also often found convenient to be able to fasten a door open, and this is achieved by fixing a hook and eye on the hanging stile to the door and its architrave or alternatively to the bottom rail near the outer stile and the skirting back against which it is to open.

SPECIAL DOORS

Sliding and Folding Doors.—These are used where it would be inconvenient to have side-hung doors owing to the clear space required for opening. Sliding and folding doors are more costly than side-hung doors due to the extra cost of the fittings, but they are well worth the extra cost for many positions, especially for wide doors.

The complete doors ready for installation can be bought from specialist manufacturers or the fittings alone can be bought for fixing to doors made by the joiner. The latter method should only be adopted for small interior and for garage doors of moderate size.

Fig. 141 illustrates eight typical plans showing the various types of opening movements. A is a single-leaf door sliding either to right or left. B is a double-leaf door sliding right and left in a cavity, a type which is very useful for interiors where, for example, a lounge communicates with a dining-room. C is a double-leaf door sliding to left and right. D is a three-leaf door to slide to left or right, two of the leaves opening at will and the third remaining stationary. E is a sliding door in sections hung on a curved track which returns along the side wall so that the whole door slides along the side wall. F is a folding door, folding against the side wall. G is a two-leaf door which slides along the side walls. H is a folding door which folds into a recess on one side.

The fittings are of two types :

1. Top hung with bottom guide. The wheels are fixed to the top of the door and they run in a track fixed to the wall. A channel guide is set in the floor (see Fig. 140).

2. Floor track with top guide. The wheels are fixed to the bottom of the door and run on a track set in the floor. A channel guide is fixed to the door head (see Fig. 142).

For interior doors a rubber floor track is often used as this gives silent working and the rubber track is flush with the floor.

CHAPTER 9

JOINERY: WINDOWS

WINDOW frames are made of wood and metal, but the latter are described in Chapter 10. A window is primarily a frame set in an opening in a wall and glazed to admit light, but most windows have a certain proportion of the glazed area arranged to open for ventilation. An opening window is essentially double framed, the opening frame being attached to the fixed frame.

Types.—The chief window types are:

1. Fixed casements.
2. Opening casements and sashes:
   - (*a*) Hinged casements, side or top hung.
   - (*b*) Lifting sashes, suspended and counter-balanced.
   - (*c*) Sliding and folding casements.
   - (*d*) Pivoted casements.
   - (*e*) Casement doors or French windows.

CASEMENT WINDOWS

Casement windows are now more widely used than the sash or other types. The chief reason for this is that any width can be easily arranged, and for houses and other buildings with rooms of small to moderate size there are standard ranges of both wood and metal casements. Another reason is that in modern architecture wide windows are favoured, and they have the functional merit of spreading the light evenly across the room, and they also give a wide angle of view.

If height as well as width is desired in a casement window, transom lights can be added. The transom should be slightly above eye-level to a person of normal height standing in the middle of the room, so that it does not interfere with the view. One or more of the transom lights can be top-hung to open, and this is a very convenient means of ventilation.

Solid Frames.—The sashes in casement windows are usually side hinged, to open outwards, to frames rebated out of the solid timber, the head and side posts are all 4 × 3 inches, and the sill is generally 6 × 3 inches and of oak; and where there are transom lights above there will also be required to be a transom, which is generally 4 × 3 inches, unless some more decorative feature is required, when it will be 5 or 6 inches × 3 inches.

When the sashes are hung to open outwards, the frames are rebated

outside with $\frac{1}{2}$-inch reveals, and the transom and sill are weathered on their upper faces, also grooved and throated, and the sill, in addition, has a groove on its bottom for a metal weather-bar or a cement fillet. The outsides of the posts are sometimes given a wide groove or sinking to afford a key for the mortar.

Construction of the Solid Frame.—The posts are tenoned into the sill, which is run past them, and should be built into a chase cut in the brickwork, but is often cut off as being less trouble.

The joint between the head and the posts is a haunched mortise and tenon with a mitre on the rebate projection. The head is best when it is also run beyond the posts, but this is not frequently seen except in the best workmanship. If the frames are constructed all in oak the tenons should be pinned with hardwood pins.

Where there are several lights in the width of a casement window the intermediate posts or mullions will be rebated on both sides, the middle portion between the rebates becoming 2 inches wide on the face.

The shoulder on the outside of the tenon at the foot of the posts where they come down on to a weathered sill must be sawn at the required angle to fit.

Heads and sills will require to be grooved on the inside, and also the posts, when there is a wood lining round the opening. Where there is no wood lining a chamfered chase is formed to give a key for the plaster, which is returned round the abutment of the opening and butted against the frame.

Solid frames should be bedded in bituminous mastic or oil putty, though they are more often painted with red lead and bedded in mortar and pointed round in cement.

SASH AND SOLID-FRAMED CASEMENTS

The sashes for casement windows consist of stiles, top and bottom rails, and bars if required. They are usually hung at the side to open outwards, or if fixed in transom lights they are generally hung at the top to open outwards. In both the dimensions and construction are the same.

Each sash that is made to open is hung with a pair of $2\frac{1}{2}$-inch or 3-inch butts, and is secured at the other side with a casement fastener, known as a cockspur fastener, and is provided in addition with a stay, working either over a pin or through an adjustable slot, so that the position of the window when open may be adjusted as desired.

The usual dimensions for the top rail and stiles or side rails are 2×2 inches or $2 \times 1\frac{1}{2}$ inches, and the bottom rail, with its splay cut and throated on its under surface, is 3×2 inches or $3 \times 1\frac{1}{2}$ inches. Bars may be from $\frac{3}{4}$ inch to 2 inches, square, rebated, or moulded, according to design. The sash will, of course, be square, rebated, chamfered, or moulded in conformity with the bars. The glass is fitted into the rebate, sprigged, and puttied.

Water and Wind Exclusion.—An objection often made to casement windows is that they are not watertight, and if cut square and fitting into square rebated frames, often there is some justification for this.

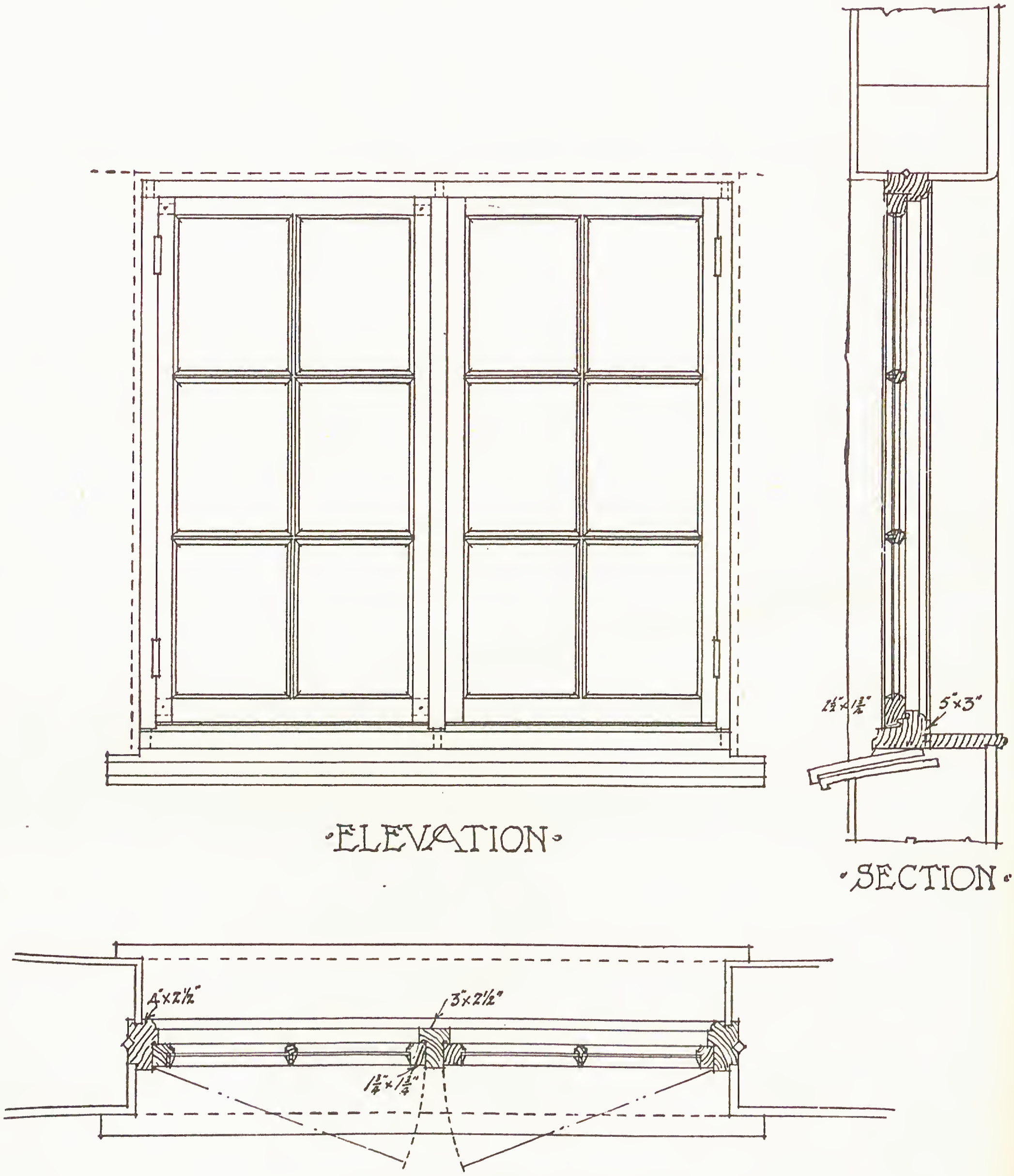


Fig. 143.—The side-hung casement.

Consequently, methods of preventing the entrance of water and wind are important.

Frames and casements may be grooved to prevent water penetrating

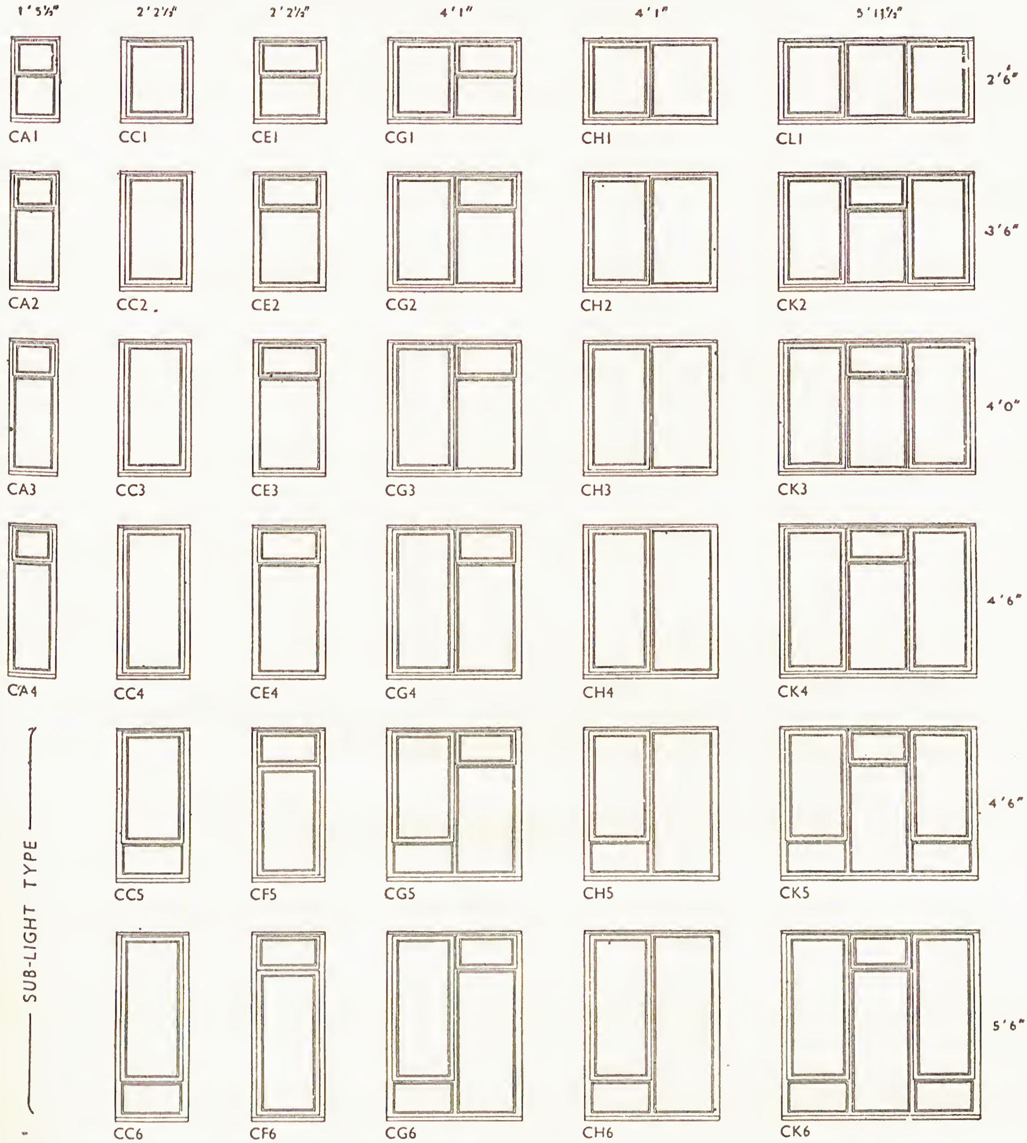
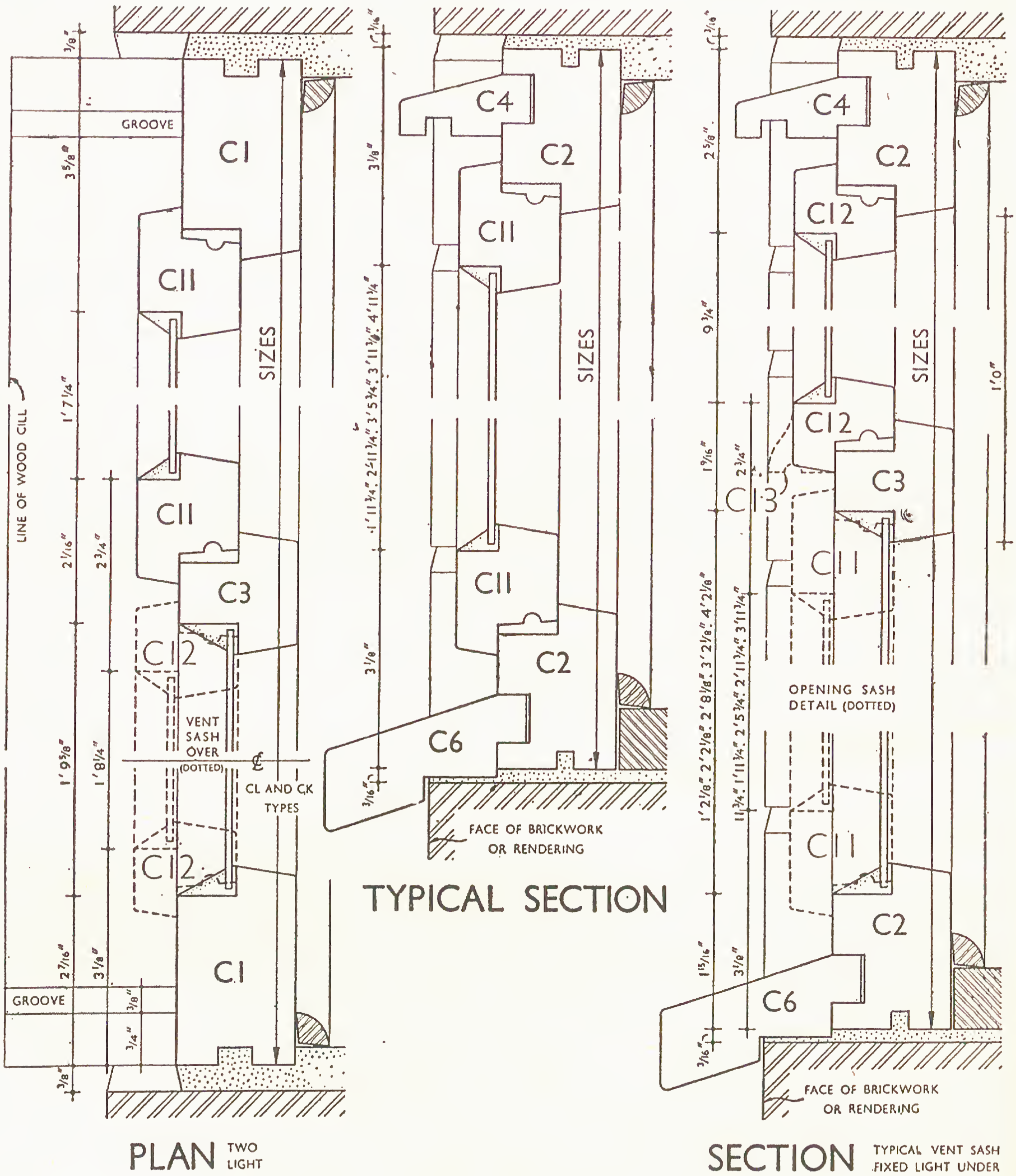


Fig. 144.—Some examples of E.J.M.A. standard casement windows (other sizes are made in this range)

by capillary action, and casements may be rebated on to the frames to provide an additional weather check. Sills should have a weathered slope to throw the water off.

STANDARD WOOD CASEMENT WINDOWS AND FRAMES

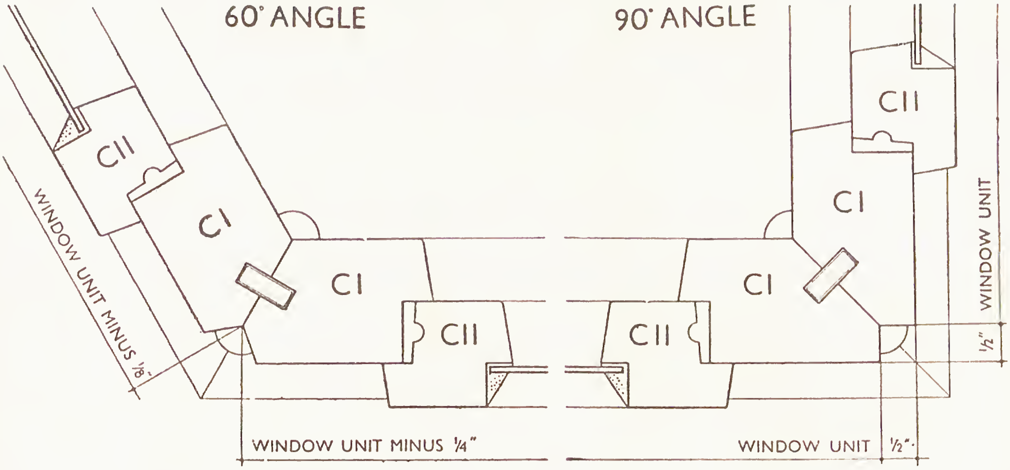
A comprehensive range of wood casement windows, casement doors, and frames has been standardised by the English Joinery Manufacturers Association (E.J.M.A.). These are illustrated in Figs. 144 and 145. The

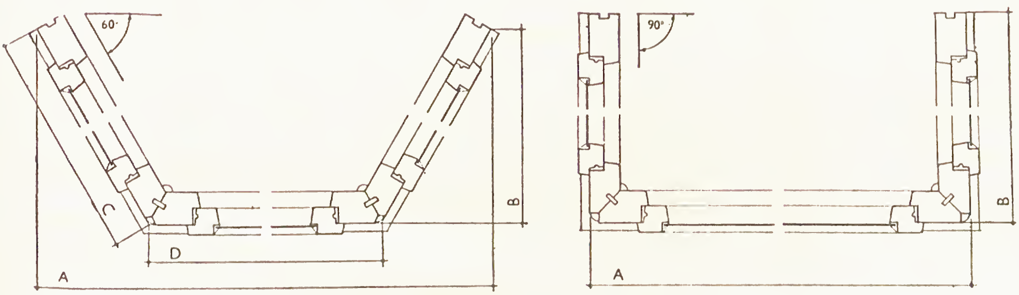


WINDOW FRAMES ARE NOT DESIGNED TO CARRY ANY STRUCTURAL WEIGHTS

Fig. 145.—E.J.M.A. standard casement details.

range of sizes is sufficient to cover all ordinary requirements for houses and many other buildings, and wider windows can be built up from Ejma standard units by means of a coupling piece, which adds $\frac{1}{2}$ inch to the combined width of the two units, and maintains the unit width of the windows so as to conform to brickwork sizes.





SQUARE BAY

TABLE OF SIZES

BAY ANGLE	NUMBER OF SIDE LIGHTS	WIDTH "A" — NUMBER OF FRONT LIGHTS: 2	3	4	PROJECTION "B"	PROJECTION "C"	DIMENSION "D"	
60°	1	6′ 4″	8′ 2$\frac{3}{8}$″	10′ 1″	1′ 11″	2′ 2$\frac{3}{8}$″	2 Front Lights	4′ 0$\frac{3}{4}$″
	2	8′ 2$\frac{3}{8}$″	10′ 1″	11′ 11$\frac{3}{8}$″	3′ 6$\frac{1}{2}$″	4′ 0$\frac{7}{8}$″	3 Front Lights	5′ 11$\frac{1}{4}$″
	3	10′ 1″	11′ 11$\frac{3}{8}$″	13′ 10″	5′ 2″	5′ 11$\frac{3}{8}$″	4 Front Lights	7′ 9$\frac{3}{4}$″
90°	1	4′ 2″	6′ 0$\frac{1}{2}$″	7′ 11″	2′ 3″	—	—	—
	2	4′ 2″	6′ 0$\frac{1}{2}$″	7′ 11″	4′ 1$\frac{1}{2}$″	—	—	—
	3	4′ 2″	6′ 0$\frac{1}{2}$″	7′ 11″	6′ 0″	—	—	—

NOTE: DIMENSIONS 'A,' 'B,' 'C,' AND 'D' FOR 60° ANGLE BAY ARE APPROXIMATE

Fig. 146.—E.J.M.A. bay-window assemblies.

The sizes shown are the actual overall sizes of the frames. These sizes, plus allowances for bedding the frames to the walls, are equal to multiples of 4$\frac{1}{2}$ inches in width and multiples of 3 inches in height, plus one brick joint in each case.

Ejma windows have been designed on data provided by careful

research. The sizes of the members have been reduced to minimum dimensions consistent with their functional requirements, thus reducing the necessary amount of painting and maintenance. Tests have proved that they are amply strong for their purpose.

The special construction details allow any expansion of the casement to take place without causing it to bind or stick in its frame, and the special construction ensures that they are wind-, rain-, and dust-tight. The casements are double rebated on to the frames, the outer rebate being obtained by lapping the casement on to the frame, offering a positive first stop to weather, while the larger clearance space in the rebates between the casements and the frames acts as an air chamber in which the pressure between the outside and inside faces of the windows can be equalised.

Obstructions to direct vision have been reduced to a practicable minimum in Ejma windows. Glazing bars have not been included in the standard range, mullions are narrow in width, and casements, which are only provided to opening lights, are of narrow sections rebated on to the frames, allowing wider glass openings, while the fixed lights are glazed directly into the frames.

In the CP and CQ ranges where two opening lights adjoin, mullions are omitted and folding sashes with rebated meeting stiles provided, allowing a completely unobstructed opening. The transoms to windows with vent sashes are well above sight-level.

The following sill-levels are suggested for various rooms :

Living-rooms and parlours—1 foot 9 inches to 2 feet 9 inches.
Dining-rooms—1 foot 9 inches to 2 feet 9 inches.
Kitchens and sculleries—3 feet 3 inches to 3 feet 9 inches.
Bedrooms—2 feet 9 inches to 3 feet 3 inches.
Bathrooms and w.c.s—3 feet 3 inches to 3 feet 9 inches.
Corridors and store rooms—3 feet 3 inches to 4 feet 9 inches.

CASEMENTS OPENING INWARDS

It is preferred by some that the casements should be hung to open inwards, though why this should be so is not quite clear, unless it is that they may be the more conveniently kept open in wet weather without admitting the rain. The hanging of curtains, however, to such windows becomes a difficulty, and the window boards become useless for the reception of ornaments, flower vases, etc.

The exclusion of the wind-driven rain, discussed above, becomes a more serious problem when the sashes are hung in inside rebates, as they have to be opened inwards.

The head of a casement frame opening inwards is throated in the rebate and both posts similarly treated, though the hanging post and stile may be fitted with the cocked bead mentioned. The sill and transom, if there is one, will require to be weathered and throated as for a

casement opening outwards, and may in addition be grooved inside and be supplied with weep holes. But there will be something additional required, as in order to open inwards the rebate is inside, so that a horizontal surface is offered on which water can collect.

Water Bars.—To prevent this leakage various forms of water bars have been devised, in most of which the covering over of this horizontal surface is the basic principle.

Water bars are formed of wood, when they are more properly termed weather moulds, or of metal, when the difficulty to be overcome of opening inwards and at the same time affording the desired protection is increased. This is overcome in some of the most modern metal water bars by forming the bar in two parts, one being fixed to the sash as a knife edge, and the other being hinged to fall when the window is opened and this is fixed to the sill.

A weather bar in wood, fixed to the bottom rail of a casement to open outwards, offers no difficulty in covering up the weathered surface of the sill ; but when the sash opens inwards the problem is more difficult, in that, to protect the weather surface, the weather bar must be given such a large projection that it is out of proportion and so becomes unsightly. This is, of course, occasioned by the fact that the sash opening inwards, the weather bar must clear the rebate on the sill and, in consequence, to afford any real shelter it must have considerable projection.

One way of overcoming this difficulty, though not entirely a satisfactory one, is to finish the vertical outside faces of the sill and the bottom rail flush, and to cut joint between them horizontal instead of weathered, forming a sinking in the sill and a throating in the bottom of the rail immediately over it. Inside the sill is another sinking, having weeping holes for drainage.

The most effective method, however, is a patent metal water bar which is hinged to fall inwards as the window is opened, there being fixed to the outer face of the bottom rail a knife edge which covers the upright weather bar on the outside when the window is closed. As the window is closed the hinged bar is raised from the flat position it occupies when the window is open by a projecting spur which passes under the bar and lifts it up against the back of the knife edge.

Casements hung at the Bottom to open Inwards.—Transom lights are frequently hung at the bottom to open inwards, when a weather board can be fixed on the hinged rail, which in its circular motion will clear the rebate on the transom, but will fit closely over the weathered face of the transom. At the head there is no difficulty, as the overhang of the rebated frame provides all that is necessary to exclude the weather.

The means of closing these transom lights is not always so satisfactory as it might be, it generally being left to a snap catch, and the light has to be closed either by a pole or by the hand of a person mounted on a chair, which cannot be described as a labour-saving device. The alter-

native method of working the sash with a cord to pull either way is better, but not good.

Transom Lights Centrally Pivoted at the sides probably provide the best method of fixing, and for these the bead has to be cut at an angle and run half inside at the bottom and half outside at the top. This type of sash must be operated by a cord tied at the bottom round a metal cleat. As the light opens inwards at the top and outwards at the bottom, the head and the transom are both cut on the splay, and on to the top of the top rail of the sash a $1\frac{1}{2} \times \frac{1}{4}$-inch bead is screwed to fit into a rebate cut in the underside of the frame head.

Casements Pivoted at Top and Bottom to open at right angles to the frame, the pivots being fixed in the centre of the head and of the sill, though not much used in modern work, provide a satisfactory method which has the advantage that the back or outside of the glass can be got at readily from within the room to be cleaned. A half bead is fixed on the inside of the top and bottom rails of the sash and the other half on the outside, and on the alternating portions of the sill and head half beads are fixed as stops. These must be mitred at the ends to fit together when the sash is closed.

THE LIFTING SASH

The question whether the lifting sash or the hinged casement is the more satisfactory is to a great extent a matter of opinion ; and it also depends on the purpose to which the rooms in which they occur are to be put.

The matter of advantages and disadvantages is mainly one of ventilation and the extent to which the different types permit of their being opened to that end, without the admission of rain and without causing unpleasant draughts, or damage to the curtains usually hung to windows.

With regard to this point, fixed sashes, of course, permit of no ventilation unless they are fitted with louvre vents, or perforated vents of the hit-and-miss pattern.

Louvre Vents in fixed windows are formed of narrow strips of glass placed one above the other, and attached at their sides to a mechanism which, on being actuated by pulling cords, fold flat (closed) or at an angle (open) in a similar manner to that of the old-fashioned venetian blind.

Perforated Vents are usually in the form of pear-shaped cuts made through the glass and arranged in a circle, and having fixed on the inside of the window a circular sheet of glass, with openings and divisions alternating, so that this may be turned by a turn-buckle fixed at the centre, either the openings or the solid interspaces being thus placed at will to coincide with the pear-shaped openings in the main glazing.

Lifting sash windows have the advantage that they can be opened at the top or the bottom, and as much or as little as may be desired in wet weather without permitting the rain to enter. If the box frame is set in

an inside reveal in a fairly thick wall, the arch of the masonry will provide a considerable protection against falling rain. However, this applies equally to side-hung and bottom-hung casements if hinged to open inwards, with the difference that the matter of the arrangements of the curtains becomes a difficulty when the casements open inwards, and the frames are set in an inside reveal, *i.e.* towards the inside of the room.

A method of enabling a lifting sash to be opened to an appreciable amount to admit air only at its meeting rails, *i.e.* the rails which divide the top from the bottom sash—is to fix from the sill, inside the room, an upright board of from 6 to 12 inches in height, and so fixed that it fits fairly tightly against the bottom rail of the lower sash. By this means the lower sash may be raised to the height of this board without allowing the passage of air or rain at that point, but at the same time affording the admission of air without rain and draughts at the space so formed between the meeting rails. The current of air so admitted will be given an upward tendency.

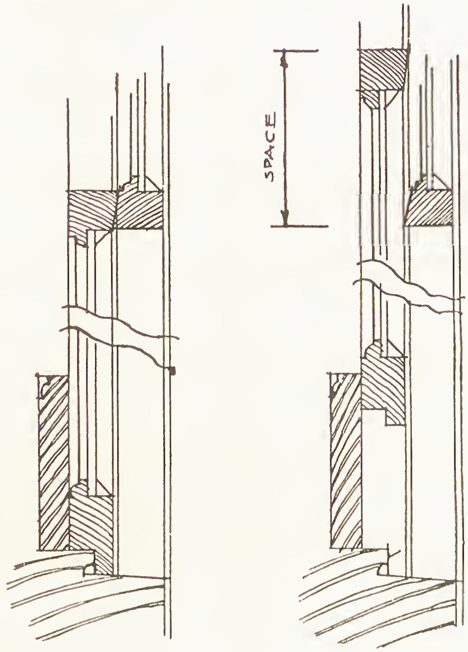


Fig. 147.—Ventilation with sash window.

A lifting sash, at most, never permits more than half the window area to be opened at a time, unless specially constructed to do so; whereas the whole of a casement window may be opened at the same time if all the sashes are hung to open. However, as this is rarely so—every alternate casement sash being usually fixed—this gain is more imaginary than real.

Specially constructed lifting sashes to enable the whole of the window area to be opened are formed with extra long weight attachments and traps in the window board communicating to boxed spaces under the window board, into which the two sashes may on occasion be completely lowered. But this form of construction is rather too expensive to be in general use.

Transom Lights to casements, if top hung, should be made to open outwards, but if bottom hung, to open inwards, when if the spaces at their sides be fitted with a hopper an upward direction will be given to the air admitted. This form of window is much used in hospitals and other public buildings, in which it is desirable that downward draughts of cold fresh air should be excluded. Centrally pivoted sashes, fixed horizontally, are also serviceable to this end.

There are certain composite windows which have lifting sashes in the

lower portion and top- or bottom-hung casements in the transoms; these are more utilitarian than pleasing architecturally.

Masonry Openings.—The openings left by the bricklayer or mason into which the window frame is to be fixed is a reveal, either on the outside or on the inside. In either case the width of the reveal for boxed frames should be $4\frac{1}{2}$ inches and for solid frames $2\frac{1}{4}$ inches, both being fractions of a brick.

THE BOX FRAME

This consists of a wooden trough or elongated box at the sides, where it is closed in on the fourth side with a back lining, and at the top, where it is a three-sided open trough and an oak sill.

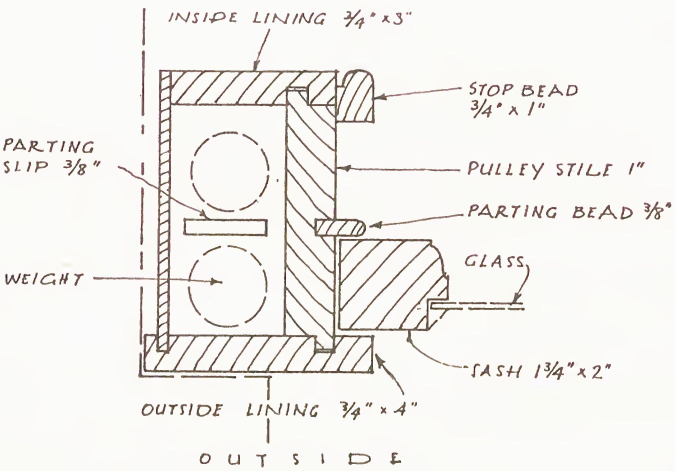


Fig. 148.—Detail of box frame for sash window.

The side boxes or troughs are constructed of:

A Pulley Stile, $1\frac{1}{2}$ inches thick by at least $4\frac{1}{2}$ inches wide rebated and let into grooves at both ends into the linings, inner and outer.

Down the centre of the outside face of the pulley-stile a groove is run, into which a $1 \times \frac{1}{2}$-inch wide *Parting Bead* is sunk to act as a guide separating the upper from the lower sashes. On the inside of the pulley stile there is a *Parting Slip* dividing the box into two equal portions, and separating the weights attached to the upper and lower sashes.

Near the bottom of the pulley stile there is a portion cut out, known as a *Pocket Piece,* to afford access to the weights. This is rebated and chamfered at the top and rebated at the bottom, and grooved along its outer face to continue the groove for the parting bead.

Over the junction of the pulley stile and the inner lining a rebated bead $1\frac{1}{8} \times 1$ inch is nailed to form a guide to the lower sash; whilst the guide for the upper sash is formed by the outer lining being projected past the pulley stile.

The pulley stile is housed into the sill at the bottom and butted against the underside of the head at the top. The parting strip, referred to above, is hung from the head by means of a wedged tongue passed through the head.

Just beneath the junction of the head with the pulley stile, slots with sinkings are cut for the pulleys to be inserted, the pulley being a wheel on a central pivot of the type known as a brass-faced axle pulley.

The Pocket is formed in cheaper work with chamfered saw-cut ends and fixed with screws, and at the side of the parting bead instead of centrally.

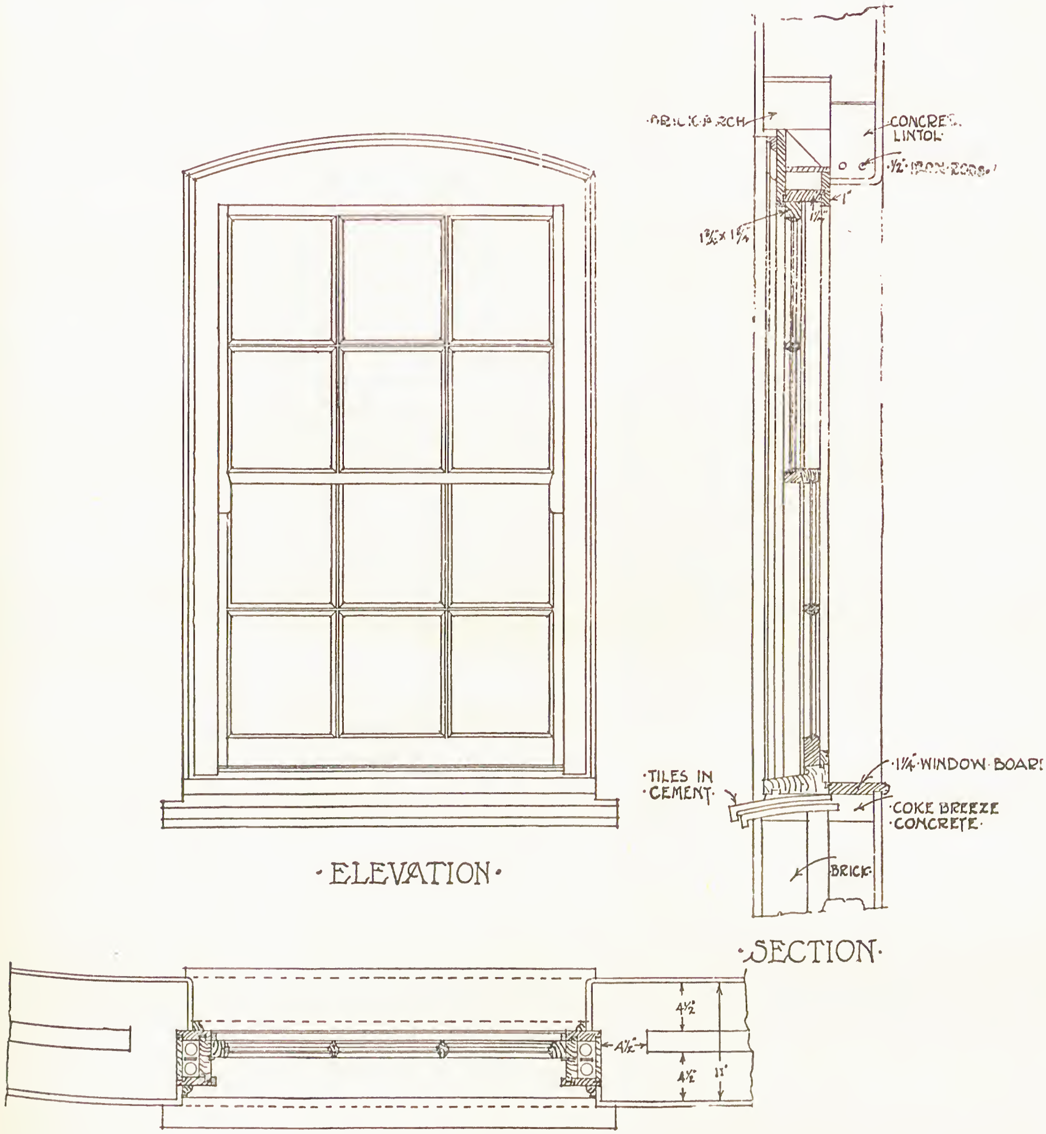


Fig. 149.—The box frame. Elevation, section, and plan.

The Inner Lining is of $\frac{3}{4}$-inch stuff grooved to receive the tongues on the pulley stile and the back lining, and on its other face it is also grooved to receive the jamb lining, where there is one. The inner lining is grooved at the bottom for a rebate cut on the window board.

The Outer Lining, 1 × 4 inches, this width being necessary to allow

for a 2-inch space for the weights, a $1\frac{1}{2}$-inch pulley stile, and a $\frac{1}{2}$-inch projection at its inner end to form the guide for the upper and outer sash referred to above. At its bottom the outer lining is shouldered and carried down for nailing to the face of the sill.

Both the inner and outer linings are continued upwards at their top ends, past the head to a distance equal to the breadth of the inner and outer linings of the head, against the cut ends of which their sides are butt jointed.

The Back Lining, $\frac{5}{8}$ inch, is chamfered along one side to fit into a groove cut in the inner face of the inner lining, and is butt jointed across the end of the outer lining at its other side.

The Parting Slip, $1\frac{1}{2} \times \frac{1}{4}$ inch, of hardwood is hung through a mortise cut in the head and wedged. This is also termed the *Midfeather*, and prevents the weights of the upper and lower sash knocking together in their passage up and down as the sashes are raised or lowered.

The Parting Bead, $1 \times \frac{1}{2}$ inch, is a strip rounded on its outer edge let into a groove cut to receive it in the face of the pulley stile to act as a separating guide for the sashes. This bead is removable when a sash is required to be taken out.

The Inner Bead forms the inner guide for the lower sash, and is angle grooved and tacked on to the corners formed by the pulley stile and the inner lining.

The Sill, 8 × 4 inches, is of oak, twice weathered, sunk and throated, and is grooved on its inner upright face to receive the rebate cut on the window board. Above the throating is a bead, which is generally moulded to close the junction of the bottom sash when closed on to the sill.

At its ends the sill has a housing cut out for the pulley stile and wedges. The horizontal beaded portion is mitred at its junction with the vertical bead on the inner lining, and a groove is cut in the sill for the reception of the jamb lining. The outer corner of the sill is cut out for the outer lining to be run down and to permit the sill to pass into the brick reveal, where the frame is set in an inside reveal.

The Pulley consists of a grooved wheel in gunmetal or malleable iron, and mounted in a flanged case. This case is screwed into the slot, and a sinking cut in the pulley stile about $4\frac{1}{2}$ inches from the head. The wheel is wider in diameter than the thickness of the pulley stile to enable the weight to hang free by $\frac{7}{8}$ inch inside the box.

LIFTING SASH

Lifting sashes are to be distinguished from casement sashes in that they are generally formed wider than they are high, whilst the casement always is, or should be, higher than its width.

The top sash consists of a top rail, two stiles, and a meeting rail either chamfered or rebated, and the lower sash is formed of a chamfered or

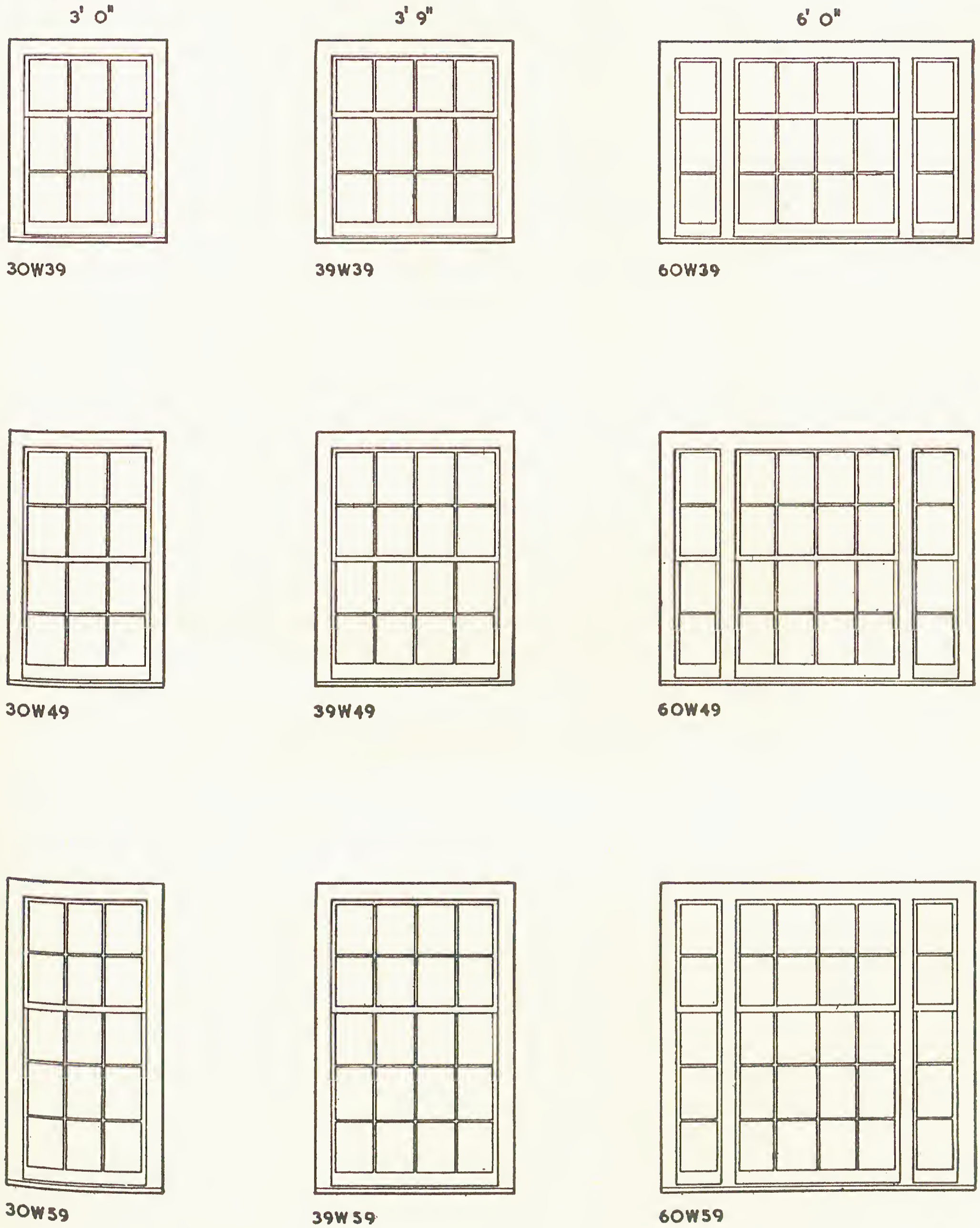


Fig. 150.—Typical examples in the E.J.M.A. sash-window range   Weight-balanced types.

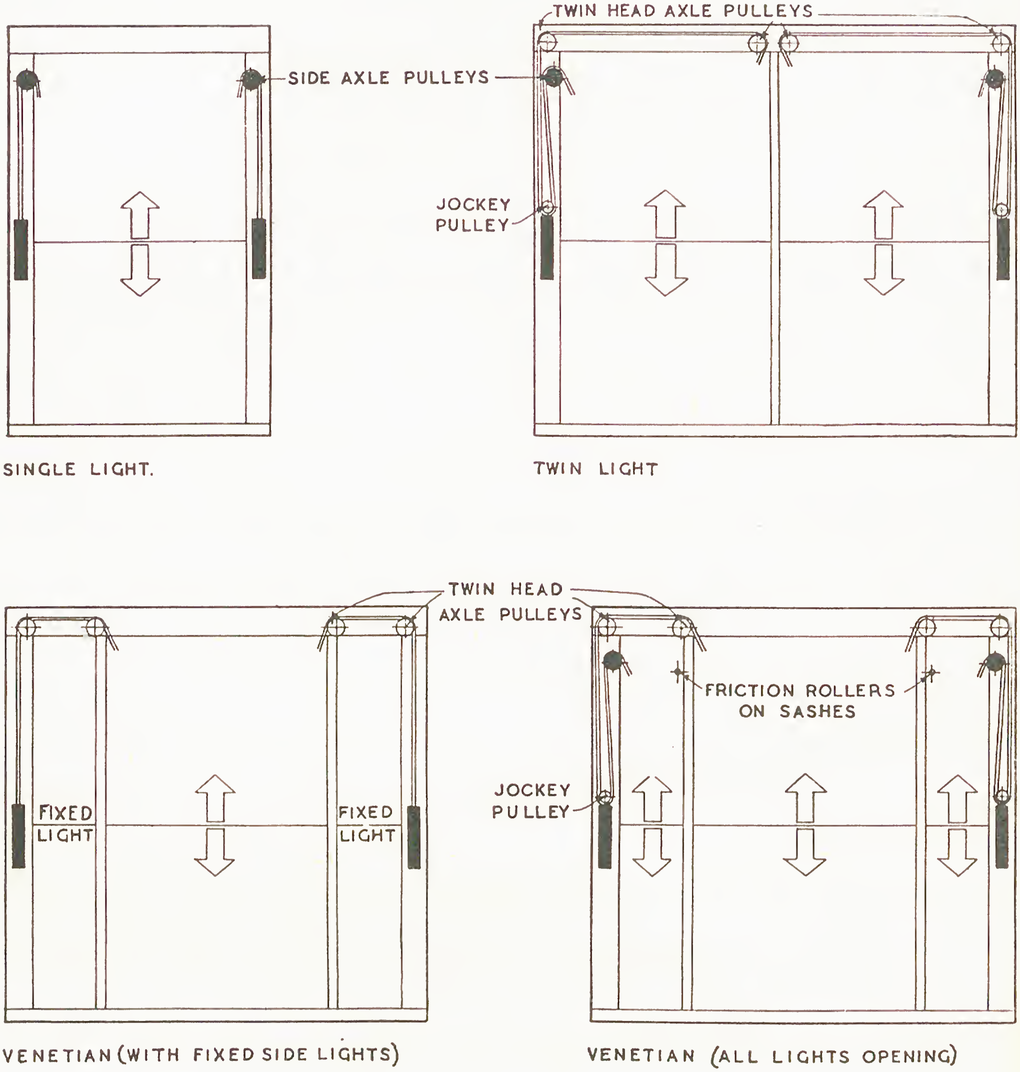


Fig. 151.—E.J.M.A. weight-balanced sash windows. Cording diagrams.

rebated meeting rail, two stiles, and a bottom rail, which is splay-cut to fit the weathering and throated, and sometimes rebated and throated. The side rails are carried down past the meeting rails to form horns, which make a secure joint with the meeting rail, and also serve to prevent the upper sash from falling down on to the sill so that its top rail goes below the meeting rail of the lower sash, from which position it is difficult to raise it.

The Dimensions of the stiles and rails ordinarily used are: stiles, $2\frac{1}{2}$ inches on face by $1\frac{7}{8}$ inches thick, back to front; top rail, upper sash, $2\frac{1}{2}$

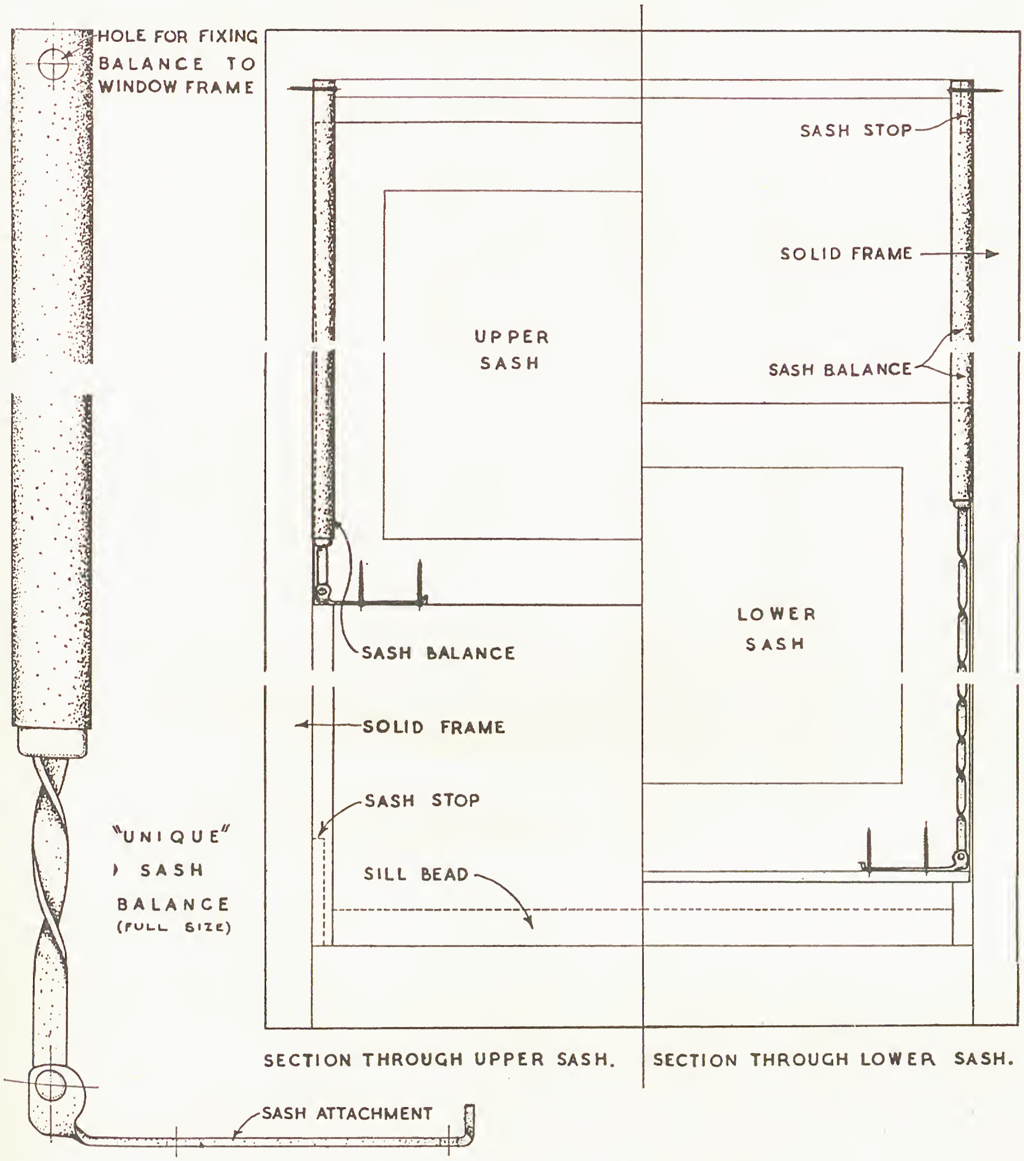


Fig. 152.—Spring-balanced E.J.M.A. sash windows. Spring-balance diagrams.

inches on the rebated meeting joint $2\frac{1}{4} \times 2$ inches; bottom rail, lower sash $4 \times 1\frac{7}{8}$ inches.

Construction of the Sash.—The meeting rail is fork tenoned to the stile. A tenon is let into the stile centrally, and in addition $\frac{1}{4}$ inch is cut out of the inside face of the stile, and a second tenon or halving is cut in the rail to fit into this. The stile is carried down below this joint 2 inches or more,

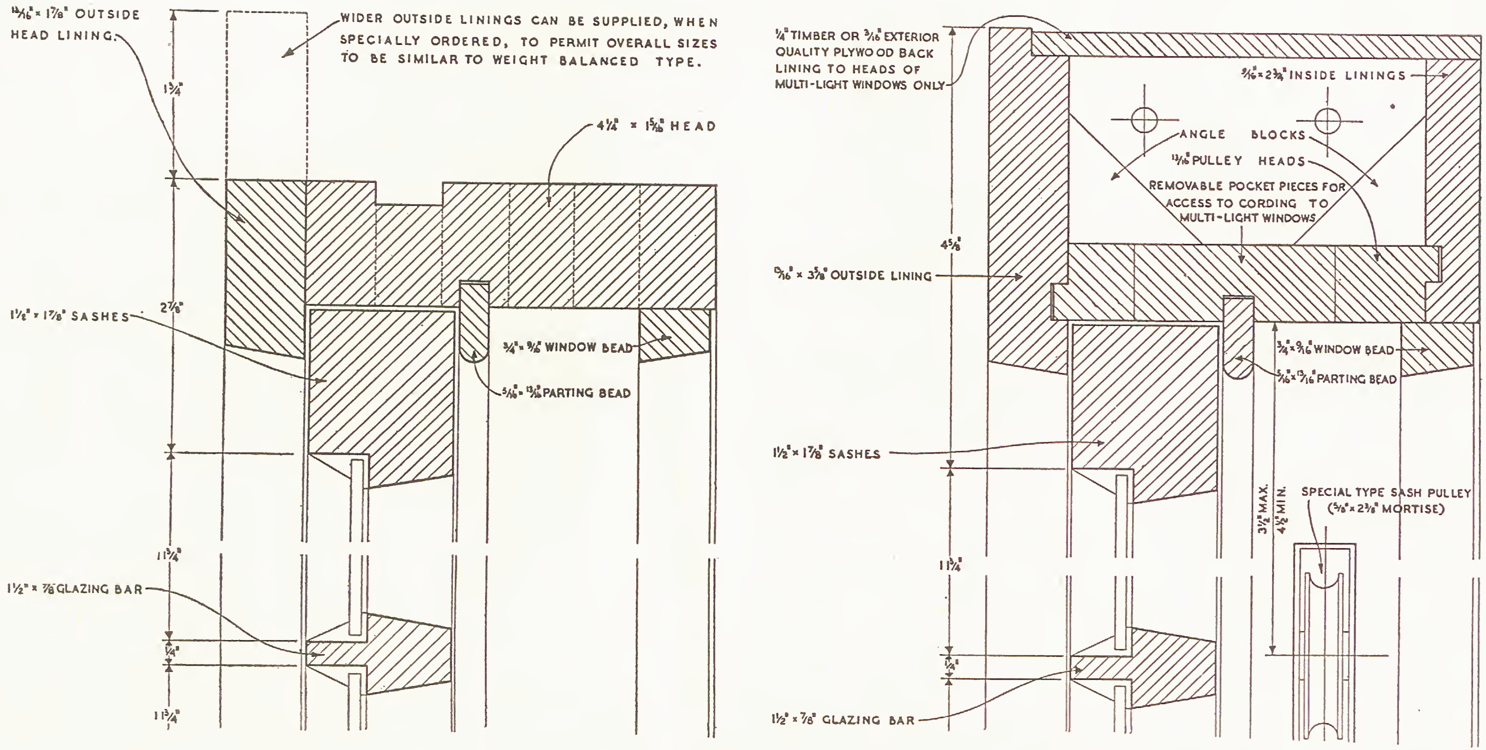


Fig. 153.—E.J.M.A. standard sash windows. Sections through heads of :—
(Left) Spring-balanced type. *(Right)* Weight-balanced type.

to suit the design, its purpose being to strengthen the joint in affording abutments to the tenons, and also, as has been said, to prevent the upper sash from falling beyond the meeting rail. Horns are sometimes also worked on the lower sash for the purpose of strengthening the joint with the meeting rail.

Where there is no horn the joint is a ***Dovetailed Tenon,*** the mouldings being scribed around on the rail in the angle of the tenon.

The stiles must be grooved with a groove having a rounded bottom on the outsides for the sash cords to fit into. This groove is about ½ inch wide and ¾ inch deep, and run down 6 inches from the top, at which point a 1-inch hole is bored at right angles. The cord is pulled through the hole and knotted, and then pressed back into the hole.

The top and bottom rails are haunched to the stiles.

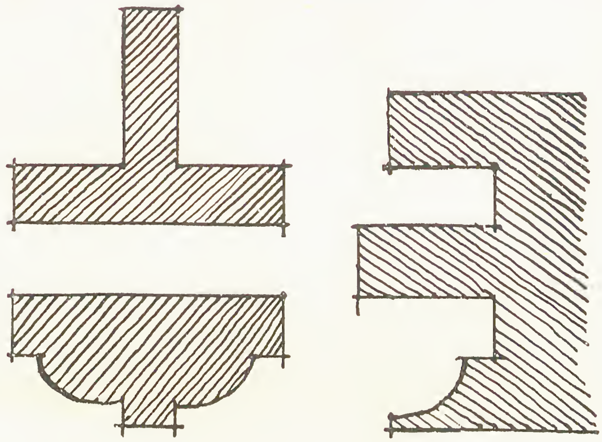


Fig. 154.—Franking.

Bars.—There is a good deal of difference of opinion as to whether bars should be provided in the sash, subdividing it into smaller panes, some claiming that to do so obstructs the view and considerably increases the labour of cleaning, whilst others maintain that very little time is spent in looking at the view from inside a house, and that the exterior appearance of the building is much improved thereby. These points are doubtless all matters of opinion in which the individual must suit himself; but of the fact that bars strengthen the sash and very considerably increase its rigidity there can be no doubt. The upright bar is run through the horizontal bar, and the mortise for the bars should be run right through, so that they can be wedged, though where the stiles and rails are short, stub tenons are sometimes used.

The intersections of the bars are formed by halving and mitreing, the halving being on the line of the rebate. Alternatively these joints may be constructed by a method known as *franking,* which is a form of reversed haunching (see Fig. 154). The moulding is scribed by machinery.

Mullion Lifting Sash Windows are formed either by having the weights in the mullion to work the sash of both the windows on either side, the weight being fitted with a pulley and the cord continuous from sash to sash, which is termed *Single Boxing,* or the box is framed double size, containing two weights side by side, hung separately.

Hanging the Sash.—The sashes may require planing before being

fitted, the desired object being to have them just sufficiently tight to resist any tendency to shake, but at the same time to slide freely up and down. They should be weighed with the glass, to be sure of getting the right weights to counter-balance them—the combined weight of two weights being slightly more than that of the sash and glass—for the upper sash in order that it may be kept closed, whilst for the lower sash the combined weights should be less than the sash and glass, so that it may remain down when the window is closed.

In threading the cords a piece of lead is attached to a string which is tied to the cord so that it may be dropped down the groove and pulled out of the pocket. The cord is nailed temporarily to support the sash, the outside cords being fixed to the top sash, and the cords are then attached to the weights, the nails being removed, and the pocket pieces and parting beads being inserted in their respective positions. The sash cords are either fixed to the sash by being knotted as described above, or they are simply let into the groove in the stile of the sash. The top cords should be a little shorter and the bottom a little longer than the measurement would suggest, to prevent the weights from either resting on the sill at the bottom or knocking the back of the pulley stile at the top. When the cords have been cut the required length and the weights attached, they are pulled up and nailed, so that they may be attached to the frames at the other ends. When removing this temporary nail hold the cord in the hand so that no sudden jarring is caused by the weight falling suddenly or it may break away and be difficult to retrieve.

Solid Mullions are sometimes formed to windows having side lights, which are fixed and not hung to open. The sash cords to the centre window are then run over pulleys at the top of the solid mullion and across the head of the fixed sash and down the box at the outside of the fixed sash, in which they work up and down attached to weights in the manner already described.

FRENCH WINDOWS

French windows, though actually used as doors, are really enlarged casement windows hung to open inwards, both sashes being hinged; some form of stop and rebating of the shutting rails is required. Also the matter of the exclusion of rainwater becomes a problem of some seriousness, as the area is larger than that of a window and the opening is inwards.

In general construction the French casement is the same as that of the window, but that the closing stiles, instead of fitting into a rebate in the frame, come together. The best form of closing joint for these is a hook rebate on the splay. In addition, to exclude wet and draughts, a long bolt, termed an espagnolette bolt, is run the entire height of the door along one of the meeting rails and is operated by a mechanism which, with one turn of the handle, shoots the bolt at top and bottom and in the centre at the same time. An improvement on this is the Janus fastening.

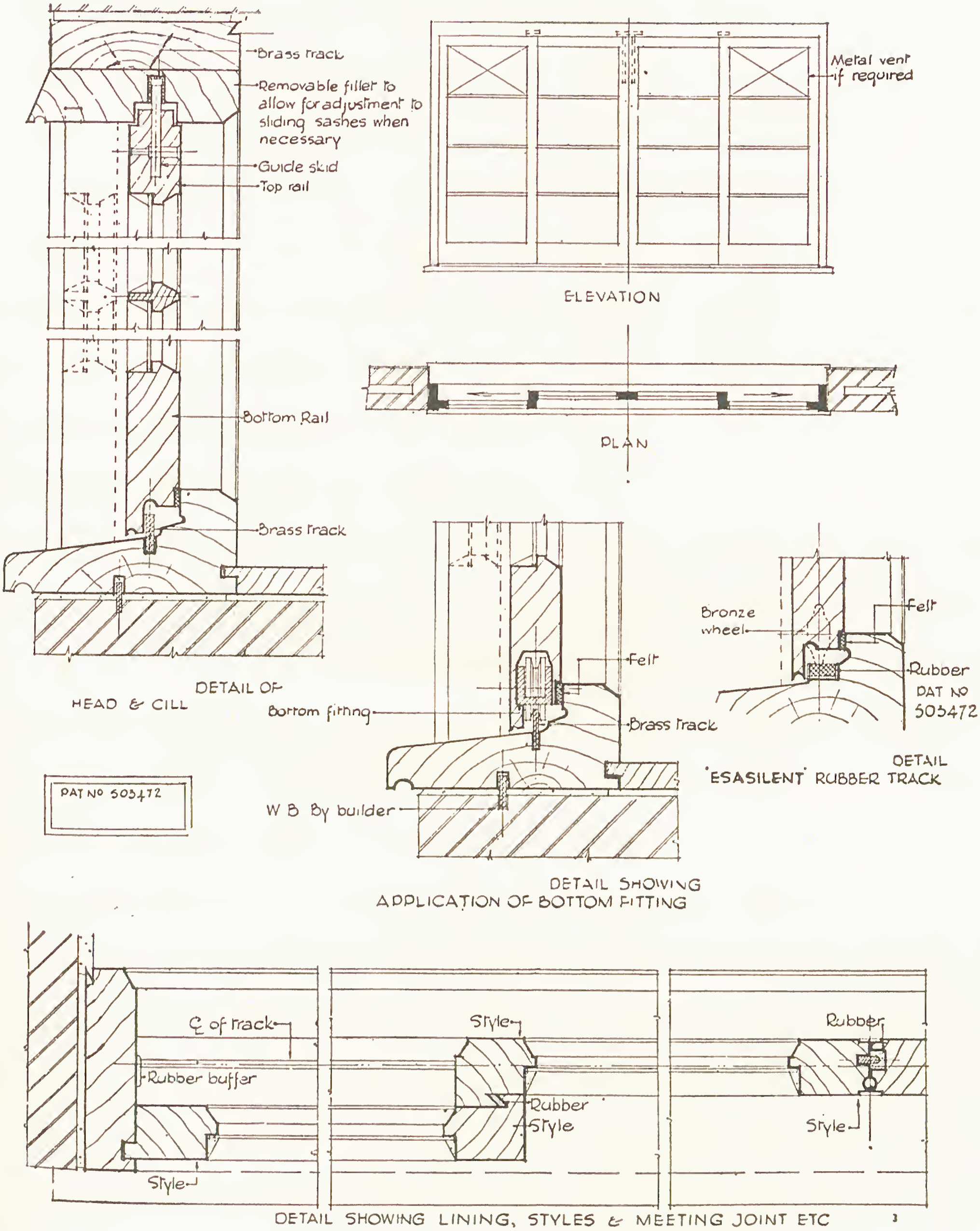


Fig. 155.—Esavian sliding window. Type 200.

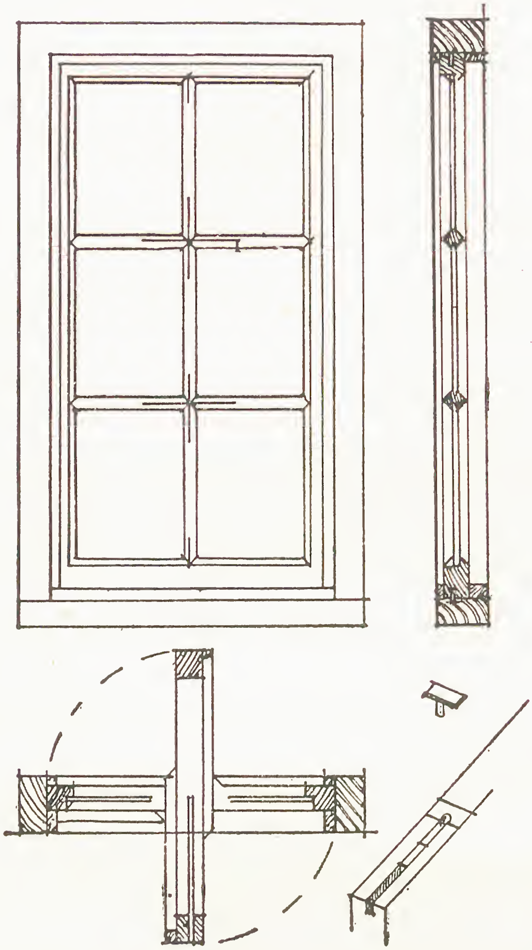


Fig. 156.—Casement window, centre pivoted top and bottom.

This, in place of the long bolt, has a strip of metal which, as well as working up and downwards at top and bottom, also moves horizontally into a slot formed to receive it in the shutting edge of the other casement. This effectively seals the shutting joint from draughts or rainwater, and it also reduces the tendency of the sash to twist.

The Sill in French casements requires additional care as, opening inwards, it is more liable to admit water.

The ordinary method of fixing an upright metal water bar is not good, as the bar, though a slight projection, is very liable to cause accidents from stumbling. Probably the most effective bar is that already described above for ordinary casement windows and known as the "Adam's" patent water bar, with the hinged flap and knife edge.

These doors will require three hinges each, and the hanging stiles are sometimes made wider than the meeting or lock stiles. The hanging stiles should be 4 inches wide and 2 inches thick, and the meeting stiles make together a width of 7 × 2 inches thick. The bottom rail should be 9 inches deep, the top rail 4 inches, and the bars dividing the glass not less than 1 inch wide on the face.

Frequently these doors are not glazed to the ground, but for about one-third of their height are formed with wood panels, when a middle rail is added above the panel at least 4 inches wide.

Over the heads of French casements it is usual to form fanlights, when the head of the frame over the doors becomes a transom 4 × 3½ inches. The doors are hung to door posts 4 × 3 inches, and these are carried up above the transom and jointed to a 4 × 3-inch head over the fanlight. The transom, head, and sill should be run through the posts which are tenoned to them. The transom light, or fanlight, is formed as has already been described for transom casement windows, and it is advisable, as the

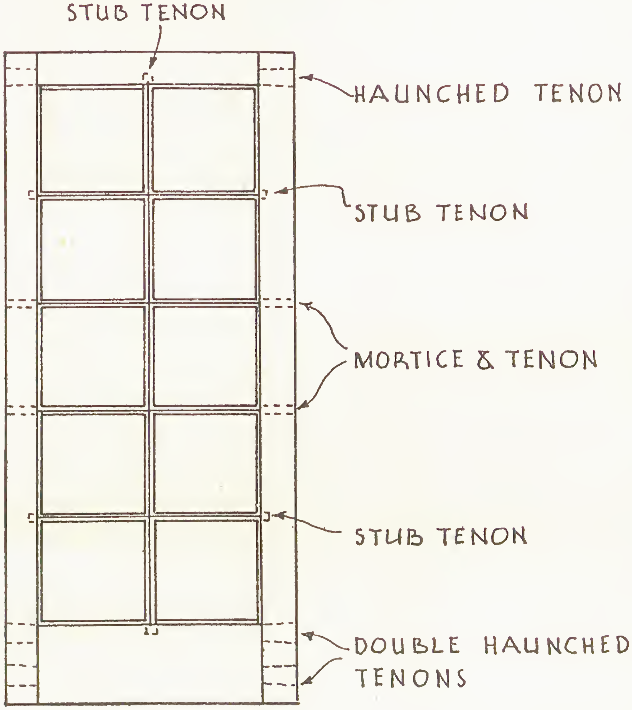
frame, 4 × 4 inches, is large, that double tenons should be used in the jointings.

The opening is often splayed at the jambs and a $\frac{3}{4}$-inch lining is fitted into the frame at one end and into an architrave at the other with tongued and grooved joints. A plinth block terminates the architrave at its base in the same manner as was described for doors, and against these blocks, at their sides, the skirting is finished; also both architrave and skirting are housed into the plinth block.

IRONMONGERY

The fittings and furnishing to windows consist of hinges, $2\frac{1}{4}$–4-inch plain butts; fasteners and stays; pivots; cleats for cords; sash lifts, and bolts.

Fasteners.—The usual form of sash fastener consists of two portions, one bearing the snap-spring catch, and the other the hook that it fits over when closed; both are mounted on plates which are let in slots, cut out of the surface of the meeting rails, and screwed with two screws each. The hook being curved and wider at the closed position than at its end has the effect of drawing the upper sash towards the lower as the snap catch is drawn across it. The catch is screwed to the horizontal face of the outer meeting rail and the hook is fixed to the top horizontal face of the inner meeting rail.



FRENCH WINDOW

Fig. 157.

Stop to prevent rattling of sash windows can be formed out of hinges, having one leaf longer than the other. They are screwed one at each side of the bottom sash on the meeting rail with the shorter leaf on the meeting rail. The longer leaf opened out and pressed against the side rail of the upper sash will act as a wedge. Failing this, hardwood wedges fitted with short chains and screwed to the sash should be provided.

Sash Lifts are plain, flat, bent hooks screwed to the bottom rail of the lower sash, or alternatively they consist of sunk plates.

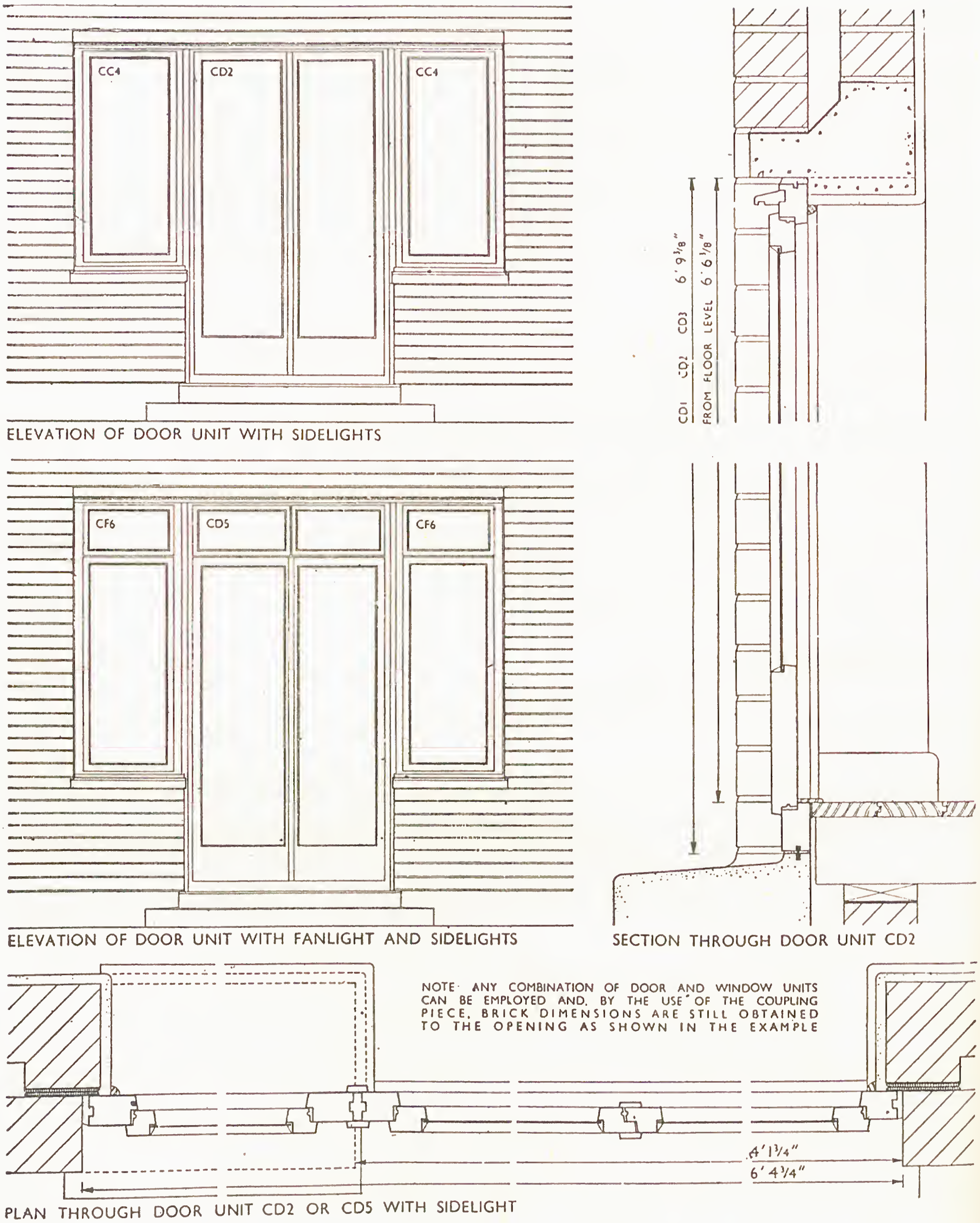


Fig. 158.—E.J.M.A. standard casement doors with fanlights and sidelights.

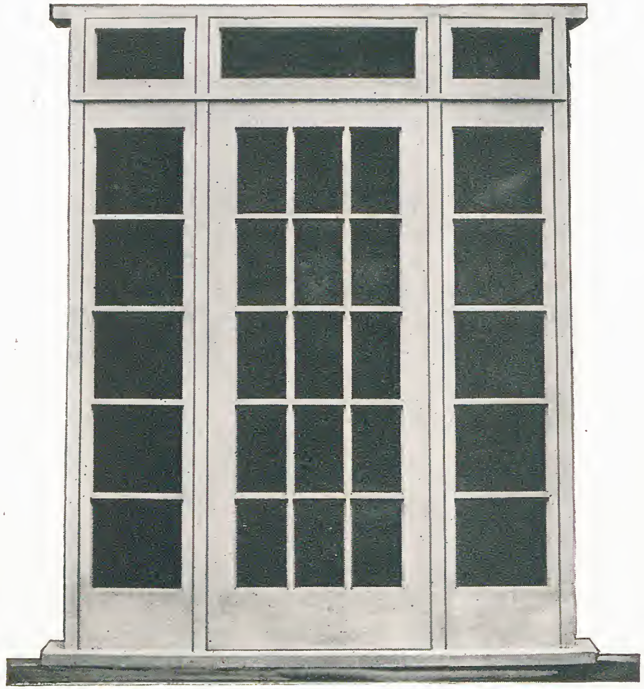


FIG. 159.—CASEMENT DOOR WITH SIDE AND TRANSOM LIGHTS.

(Courtesy of H. Newsum, Sons & Co., Ltd.)

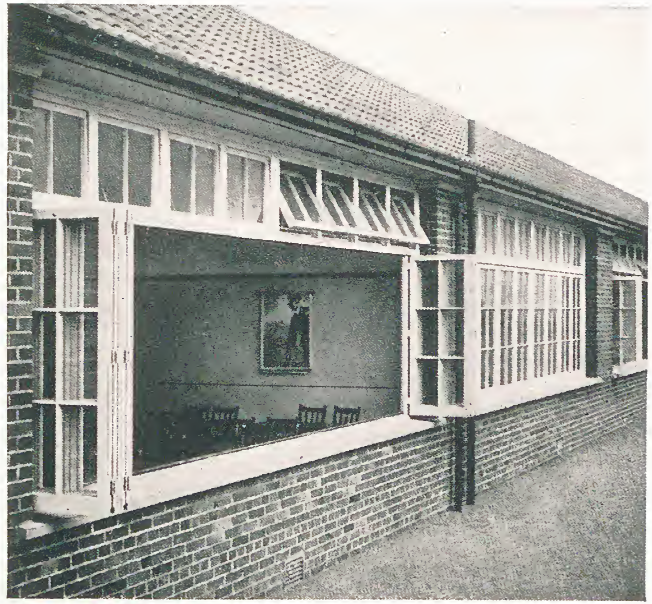


FIG. 160.—ESAVIAN SLIDING WINDOWS IN A SCHOOL.

(Biram & Fletcher, FF.R.I.B.A., Architects.)

Casement Fasteners.—The cockspur fastener consists of two parts, one plate bearing the hook which is screwed to the face of the frame or alternatively a slotted plate screwed to the side of the frame, and the other, a plate attached to which and working on a pivot is the handle termed the cockspur. The slotted plate should be fixed at a slight angle from the vertical to enable the cockspur to draw the sash towards the frame as it is tightened up.

Casement Stays.—Though there is a variety of patterns of stay designed to hold the sash fixed in the open position, probably none is more satisfactory than that which consists of a rod perforated with holes and fitting over a pin screwed into the sill. The disadvantage of these is that in time and with wear they may begin to rattle, but the advantage they possess over those forms of stay in which the rod runs through a slot tightened with a screw is that whilst with wear the latter slip, the former cannot.

Stainless Steel.—All the above fittings and those to doors also are to be obtained now in stainless steel and in a material known as "Birmabright," the latter from Messrs. James Gibbons.

"Semprex" stainless steel is supplied by Messrs. Nettlefold & Sons, Ltd., and will retain its brilliance under ordinary atmospheric conditions, provided that the fittings are given occasional attention. Should a deposit form, this is best removed by means of a damp cloth with powdered pumice stone or sand. The following are the dimensions of some of the usual fittings now made in stainless steel:

Front Entrance Door Knockers, 7 inches over all; Postal Handle and Knocker combined, 9 inches over all, $5 \times 1\frac{1}{2}$-inch opening; Centre Door Knob, $2\frac{3}{4}$ inches, circular on diamond plate; Centre Door Knob, oval, $4 \times 2\frac{1}{2}$ inches; Door Handles, grip pattern, $14\frac{1}{2}$ inches over all, $10\frac{1}{4}$-inch grip, also $8\frac{1}{2}$-inch and 11-inch; All Cast Lever Handle, back plate, $3 \times 1\frac{1}{2}$ inches, handle $3\frac{1}{2}$ inches; Interior Door Knobs; All Cast Oval, $2\frac{1}{2} \times 1\frac{1}{2}$ inches, $2\frac{5}{8} \times 1\frac{1}{2}$ inches; All Cast Ball Knob, $1\frac{3}{4}$-inch knob, for rim or mortise; Lock Handles on plates: back plate, $7 \times 2\frac{1}{4}$ inches, handle, 3-inch grip; Ball Knob, $1\frac{3}{4}$ inches; Oval Knob, $2\frac{1}{2} \times 1\frac{1}{2}$ inches; Barrel Bolts, $4 \times 1\frac{1}{4}$ inches, $6 \times 1\frac{1}{2}$ inches, $8 \times 1\frac{1}{2}$ inches, $10 \times 1\frac{1}{2}$ inches; Flush Bolts, $8 \times \frac{3}{4}$ inch; Norfolk Latch, back plate, $10\frac{1}{2} \times 2$ inches, and Letters and Numbers from 2 inches to 9 inches. *Interior Fittings* in stainless steel include: Cupboard Turn, $1\frac{1}{8}$ inches and $1\frac{5}{8} \times 1$ inch oval; Hat and Coat Hook, 6 inches; Sash Handle, grip, 3 inches; Sash Lift, $1\frac{7}{8}$ inches; Casement Stay, 10 inches and 12 inches; Sash Fastener, $2\frac{3}{4}$ inches; Rim Lock, 6 inches; Rim Latch, 4 inches; Cleat Hooks, 2 inches, 3 inches, and 4 inches; Door Holder, with rubber contact, back plate, $2 \times 1\frac{3}{8}$ inches to $3\frac{1}{4}$ inches over all when closed.

A Door Holder will fix the door in any position by a spring action pressing a rubber stop on the floor. The door will not drag when fixed open and can be released instantly when desired.

CHAPTER 10

METAL WINDOWS, DOORS, AND METAL TRIM

STEEL and, to a lesser extent, bronze and aluminium alloys are now widely used in the manufacture of windows, doors, door frames and linings, skirtings, picture rails, shelves, and corner angles for plastered walls. Cupboards and partitions are also made of steel. Thus, many interior fittings which were formerly made of wood are now obtainable in metal.

It cannot be categorically stated that wood is inferior to metal for such purposes. Metal has the advantage of freedom from rot and warping, and if treated with a rust-proofing process is not affected by damp, but

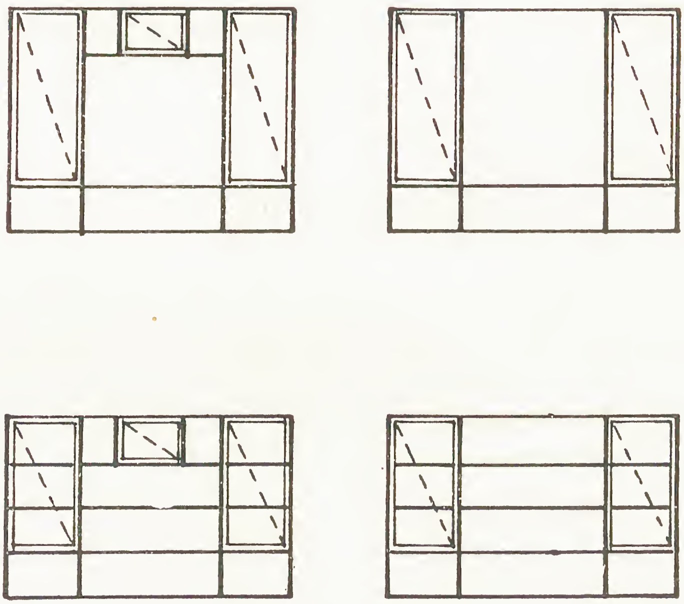


Fig. 161.—Typical standard steel windows of the " sub-light " type. Broken lines indicate opening casements.

its thermal insulation is less than wood and it is not so adaptable. Probably these metal fittings are equal to good-quality joinery and certainly are superior to the cheapest joinery.

METAL WINDOWS

The sections from which metal windows are made, being smaller than wood sections, stop less light and economise painting. With steel windows

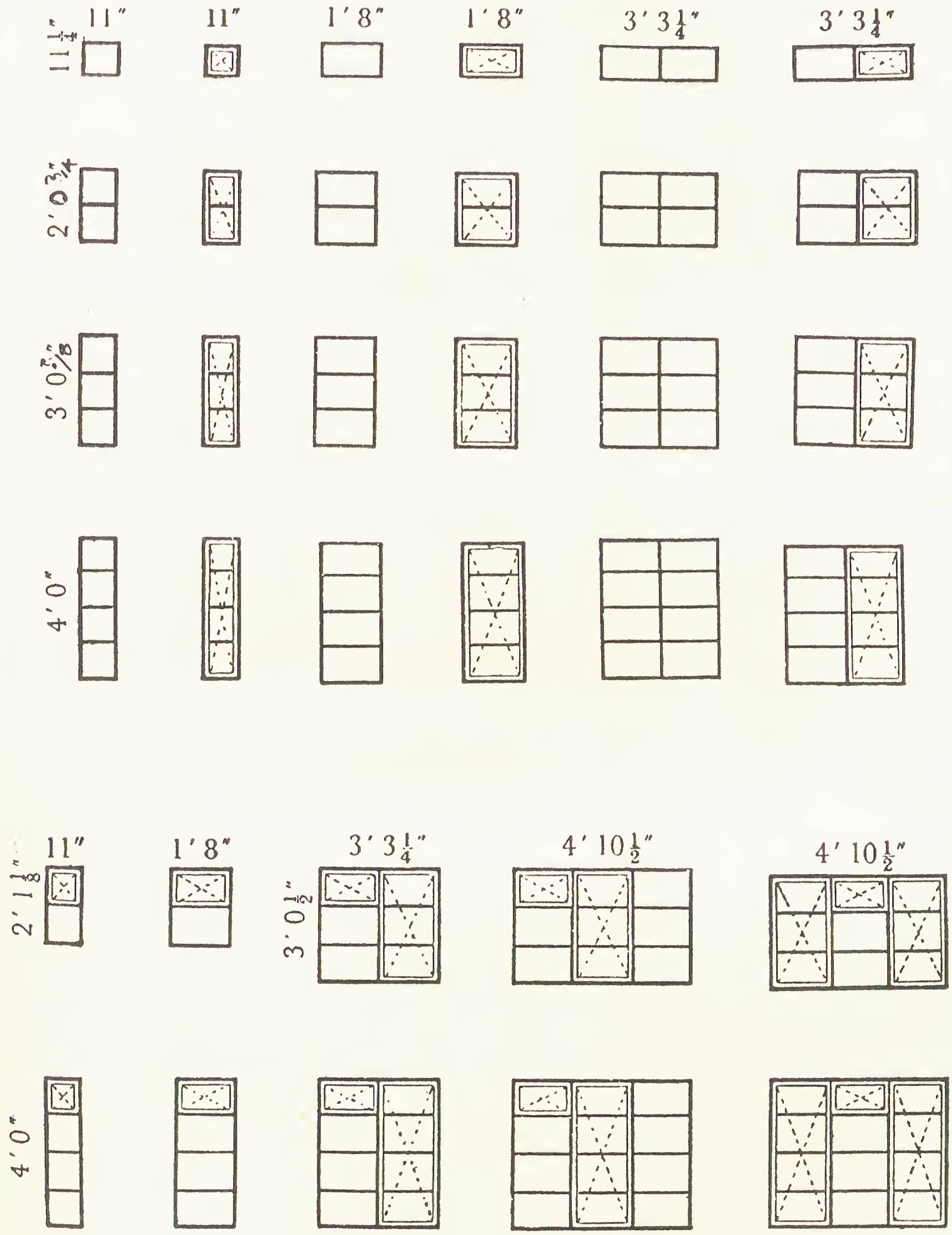


Fig. 162.—Typical standard steel windows with horizontal bars.

trouble has been experienced with rusting, but under the latest British Standard Specification (990 : 1945) all *standard* metal windows and doors must be finished by hot-dip galvanising. This should prevent

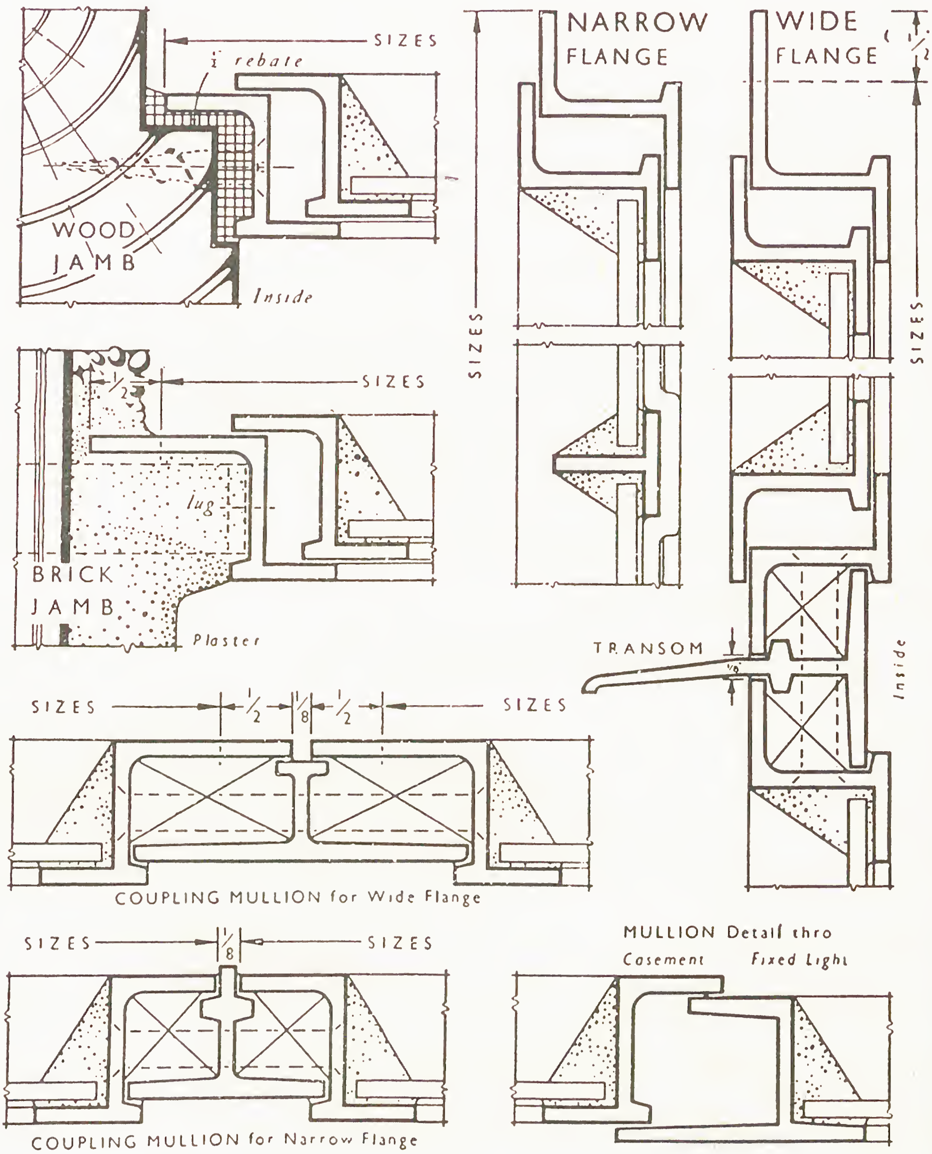


Fig. 163.—Standard steel windows; narrow and wide flanged frames, and coupling mullions and transons. (*Courtesy of Henry Hope & Sons, Ltd.*)

corrosion, but a special priming paint should be used before applying ordinary oil paint. Steel windows and doors can also be rust-proofed by zinc spraying and by a suitable proprietary process such as Sheradising

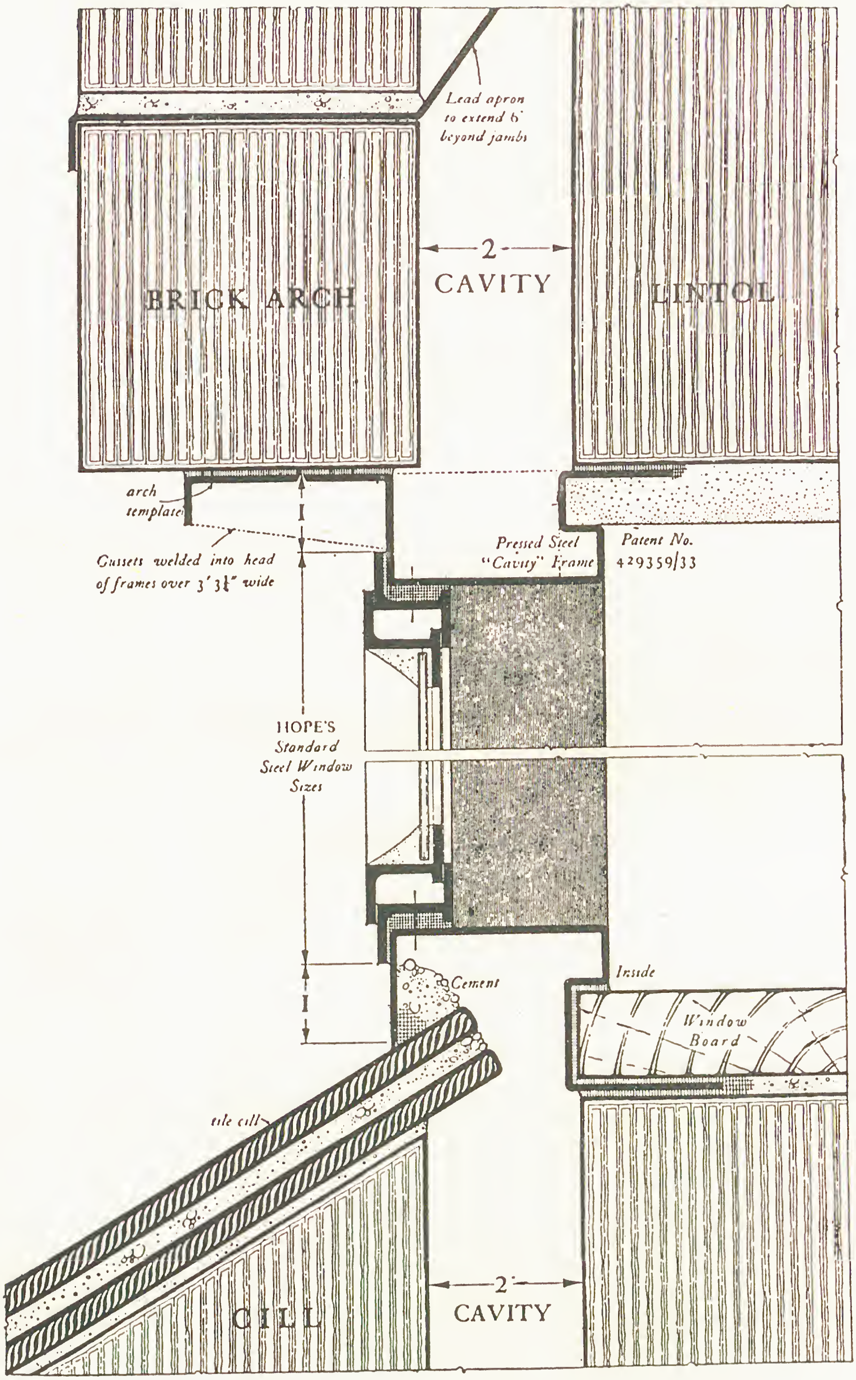


Fig. 164.—Cavity sub-frame with steel window.
(Courtesy of Henry Hope & Sons, Ltd.)

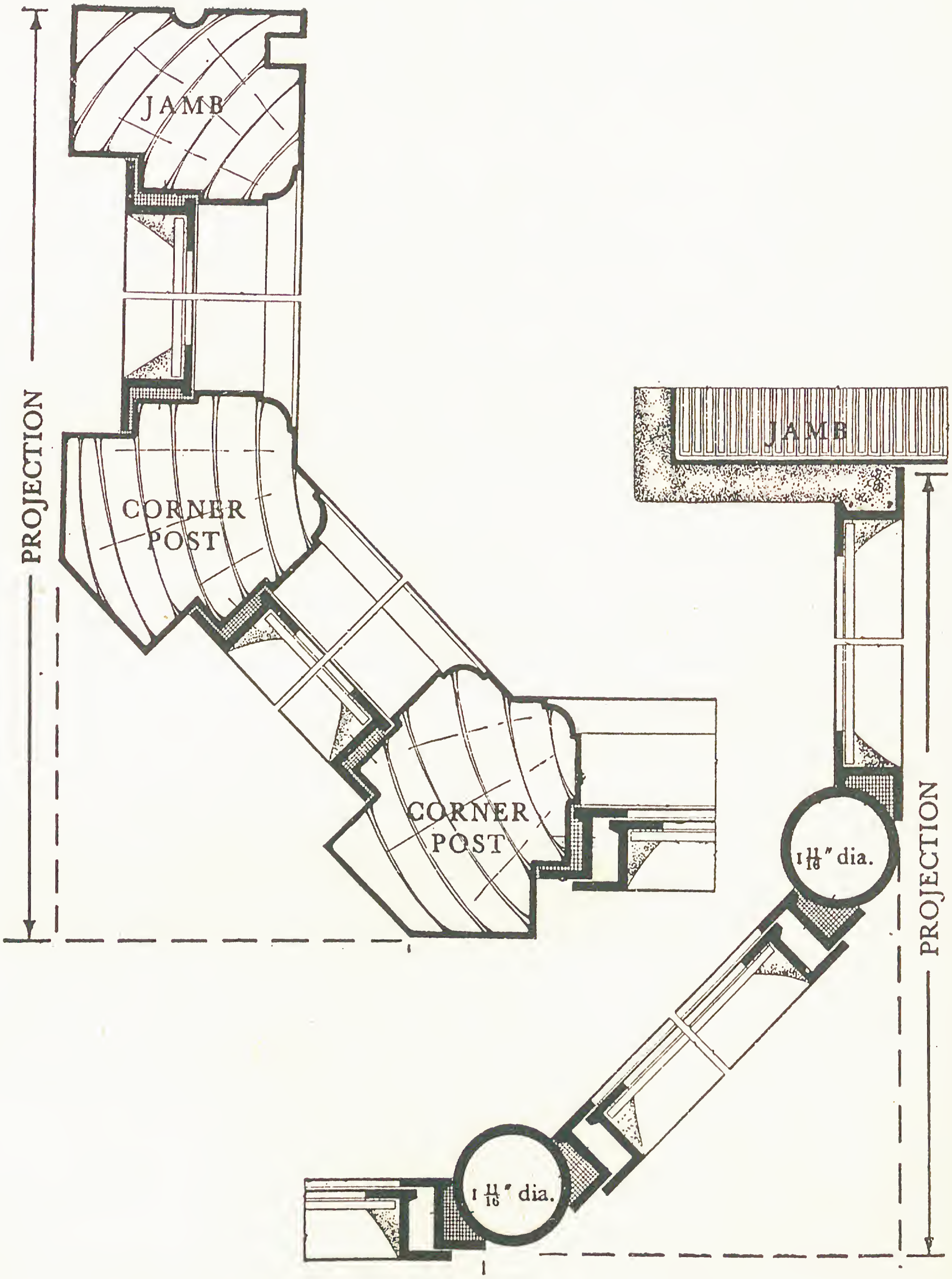


Fig. 165.—Standard steel windows in bays. (*Left*) wood mullions. (*Right*) steel tubular mullions. (*Courtesy of Henry Hope & Sons, Ltd.*)

or Parkerising. Non-rusting alloys are also used for making metal windows and doors, and these, of course, require no protective treatment.

Types.—Metal windows may be considered as :

1. Standard metal windows for domestic buildings.
2. Metal windows of medium and large sections for larger windows.
3. Metal windows for factories and warehouses.
4. Metal windows for schools and hospitals (these allow maximum ventilation).
5. Sliding and folding windows (these allow the whole of the window to be opened, leaving a clear space).
6. Double sound-resisting windows (these are used in hotels, offices, etc., in localities where noise is a major problem).

Standard Metal Windows for Domestic Buildings are made under B.S. 990 : 1945, in six heights, by five widths, in the following types : without bars ; with horizontal bars ; two heights with fixed sub-lights.

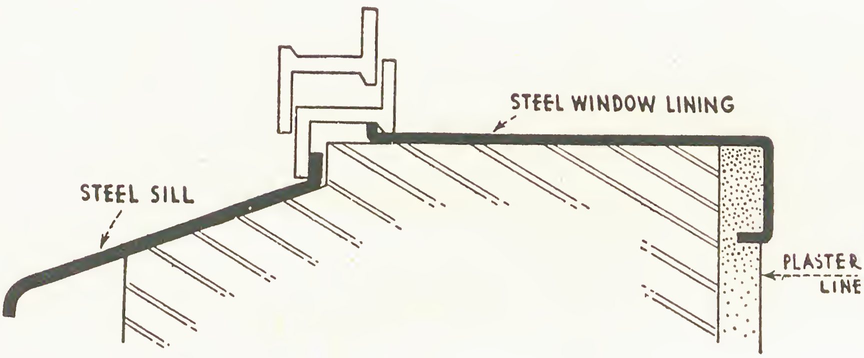


Fig. 166.—Steel window-sill linings. (*Courtesy of Joseph Sankey & Sons, Ltd.*)

In addition to the 1-foot 8-inch standard width, an additional 2-foot width has been standardised.

Larger windows than the standard range may be built up by using coupling bars, as shown in Fig. 163. These form mullions when using two or more windows to form a long window and transoms when increasing the height by the addition of transom lights.

Standard windows are fitted with brass handles and stays, and hinges with brass pins. Hinges are welded or riveted to the frames.

Ventilation is by side-hung casements and top-hung lights. The advantage of the fixed sub-light type is that the danger of children falling through an open casement is lessened, and also articles placed on the window board cannot be accidentally pushed through the open window.

It is desirable that at least one window in a room should have a small top-hung light, as this is a very convenient form of ventilation in boisterous weather.

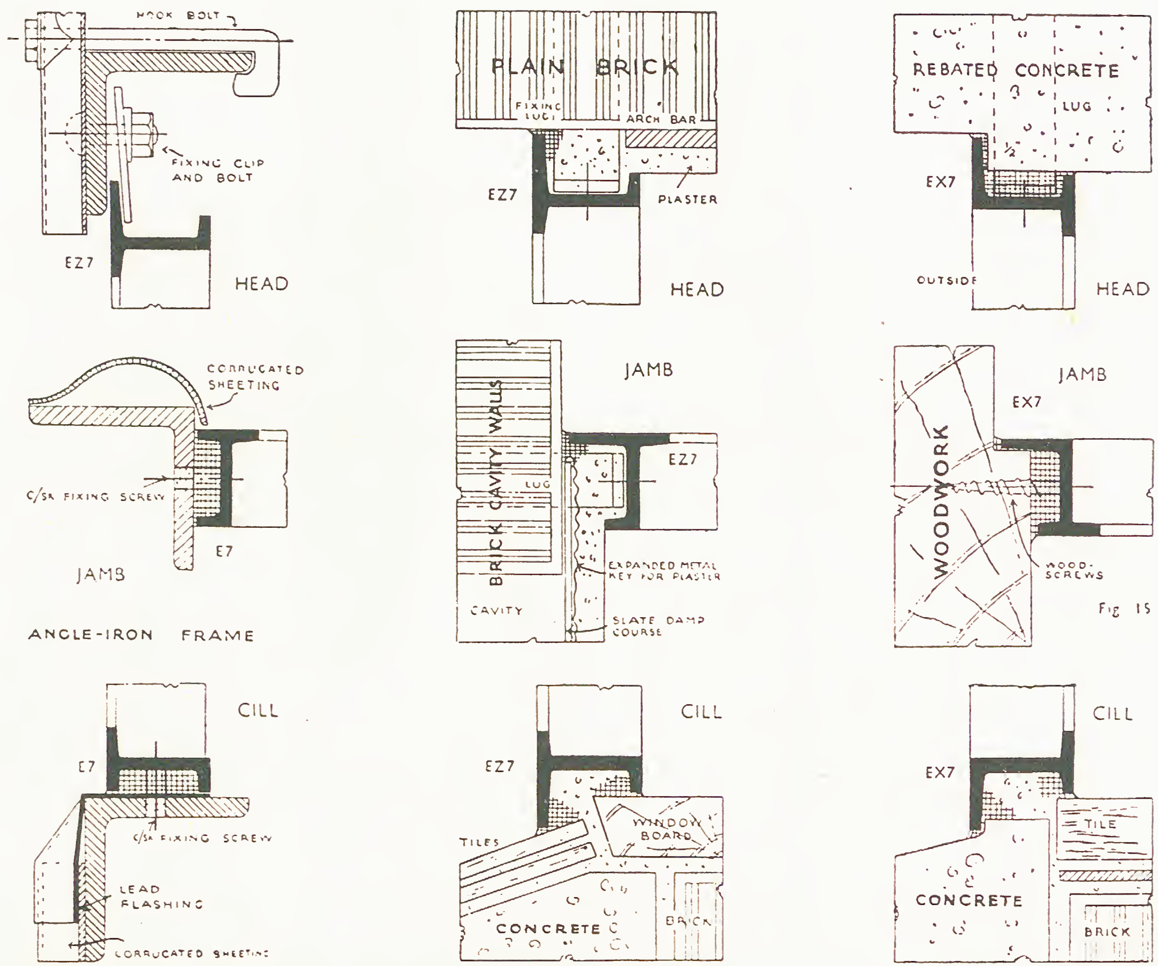


Fig. 167.—Typical fixing details for industrial steel windows.
(*Courtesy of John Williams & Sons (Cardiff), Ltd.*)

Non-Standard Windows.—The leading metal window manufacturers have their own special sections and patterns for various purposes, with a fairly comprehensive range of stock sizes. For schools, hospitals, offices,

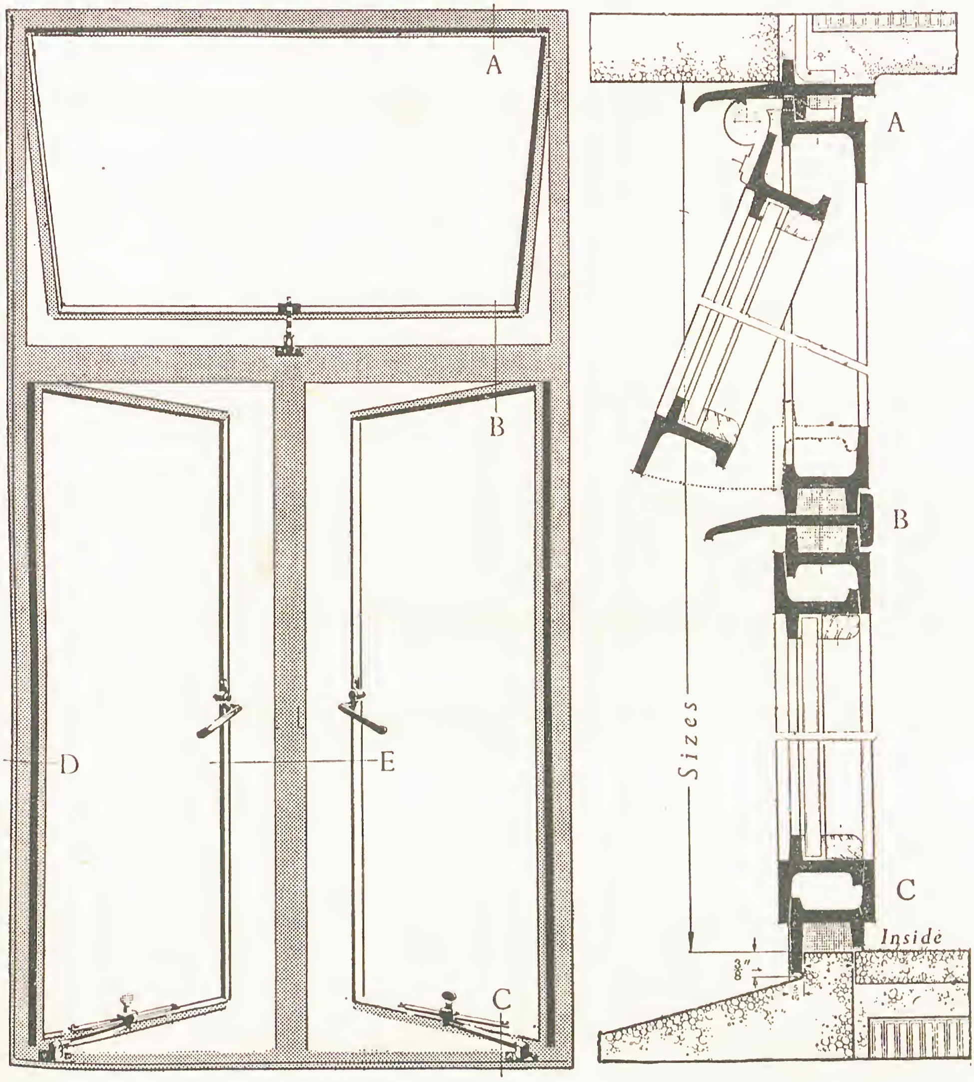


Fig. 168.—Composite window affording a wide range of ventilation and safety for cleaning from inside. The transom casement may be at the bottom, or to swing, and may be fitted with operating gear, or sub-frame and cable gear. (*Courtesy of Henry Hope & Sons, Ltd.*)

and factories windows are often made to the architect's sizes, and on large contracts the extra cost is slight.

Wood Surrounds and Frames.—Where metal windows are fixed direct to the wall jambs, head and sill lugs are provided for building-in. The standard frame is obtainable with narrow flange and wide flange,

and the latter should be used where the exterior wall is rendered or roughcast.

As standard metal windows have much narrower frames than wood, it is often preferred to fix them either in wood surrounds or wood frames. A wood surround is an outer frame, a wood frame has each 1 foot 8 inches

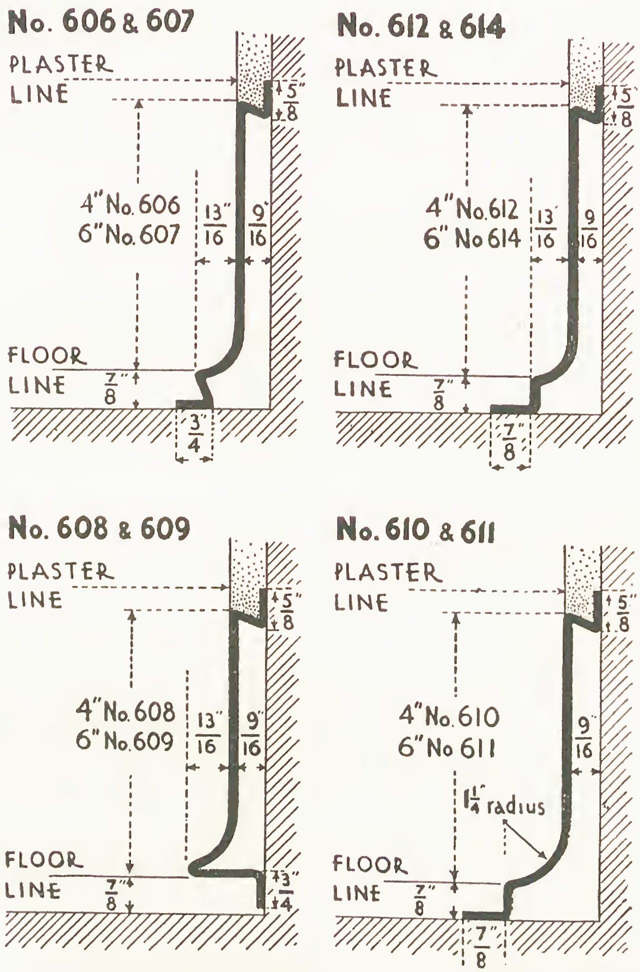


Fig. 169.—Steel skirtings. (*Courtesy of Joseph Sankey & Sons, Ltd.*)

wide window unit framed in wood, so that a two-unit window has a centre wood mullion, a three-unit two wood mullions, and so on. The wood surround is usually preferred, as it is more economical and does not interrupt the view so much.

Glazed Doors.—These doors, or French windows as they are usually called, are made single and double. Side lights and fanlights are also made for use with the doors.

For post-war house building, a range of sizes is listed in British Standard 990 : 1945. This includes two types : one without bars except for a pair to form lock rails, and the other with horizontal bars. These doors open outwards and fold back against the wall. Kicking panels are provided.

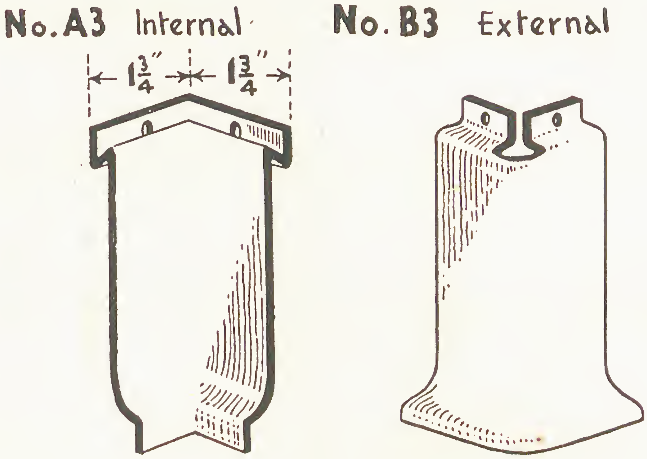


Fig. 170.—Steel skirtings : Internal and external angles.
(*Courtesy of Joseph Sankey & Sons, Ltd.*)

The doors have brass sliding bolts and striking plates, and mortise lock, brass lever handles and escutcheon plates. They are rust-proofed by hot-dip galvanising.

Glazed doors and window casements are also made to open inwards as true French casements.

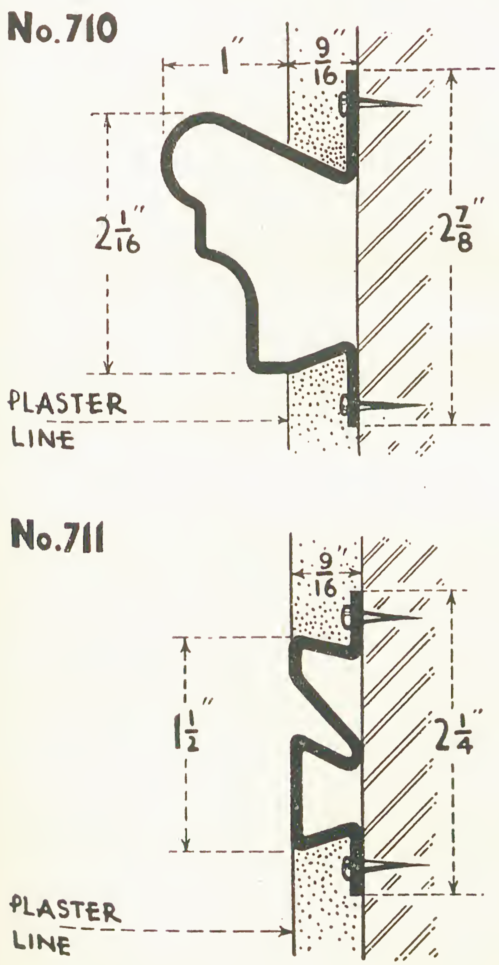


Fig. 171.—Steel picture rails.
(*Courtesy of Joseph Sankey & Sons, Ltd.*)

STEEL DOORS AND FRAMES

Steel doors with flush surfaces have been widely and successfully used in houses, flats, offices, etc. They are supplied with steel frames or linings and the complete unit remains a good fit, as no shrinkage or warping can take place.

The interior of the door is framed and the spaces filled with sound-resisting material, which also gives satisfactory thermal insulation. The frames are fitted with rubber buffers to prevent noise when the doors are closed.

Locks, hinges, and door furniture are supplied with the doors, and time is saved in fitting, compared with wood doors, which have to be fitted on the site.

Steel frames can be used with steel or wood doors. Three standard patterns are illustrated in Fig. 174. The sizes are designed to take the usual range of door sizes and a steel frame for garage doors is also made.

In fixing, the steel frames are strutted in position before erecting the partition wall. The wall is then built into the frame section and the

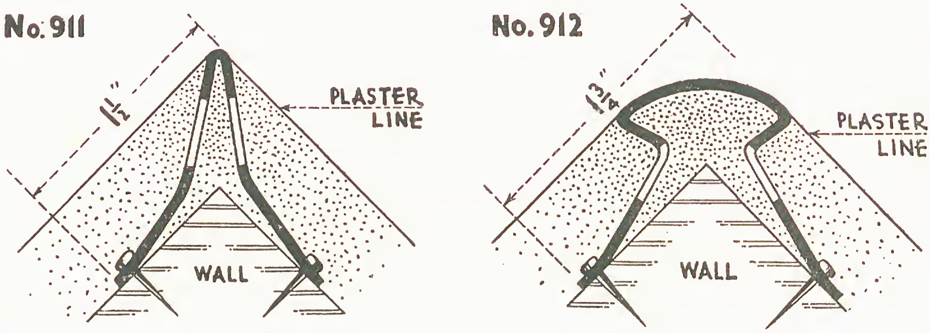


Fig. 172.—Steel corner angles. (*Courtesy of Joseph Sankey & Sons, Ltd.*)

frame lugs are also built in. The hollow space is grouted as the work proceeds. When the work has set hard the struts are removed.

METAL TRIM

Under this heading is included skirtings, window sills, picture rails, and corner angles.

Skirtings.—Various patterns are made, including a coved pattern which is very easy to clean. Suitable internal and external angles are made.

The skirtings are usually ordered in exact lengths taken from the rooms. They are nailed to the brickwork and the angle joints are covered with internal or external overlapping units, which are so designed that they allow for slight adjustment. By another method the lengths can be cut on the site with a special saw and the corners saw-mitred, or flush corner pieces can be fitted. Welding can also be used for joining corners.

The top edge of the skirting is folded back and slotted. This forms a good key for the edge of the plaster, and if desired, grouting may be poured through the slots to make a solid backing.

Other metal trim can be made at the works to dimensions taken from the site. Internal window linings, for example, can be welded up ready for fixing in place of the usual plaster lining.

Metal trim has a very neat characteristic appearance, and the available

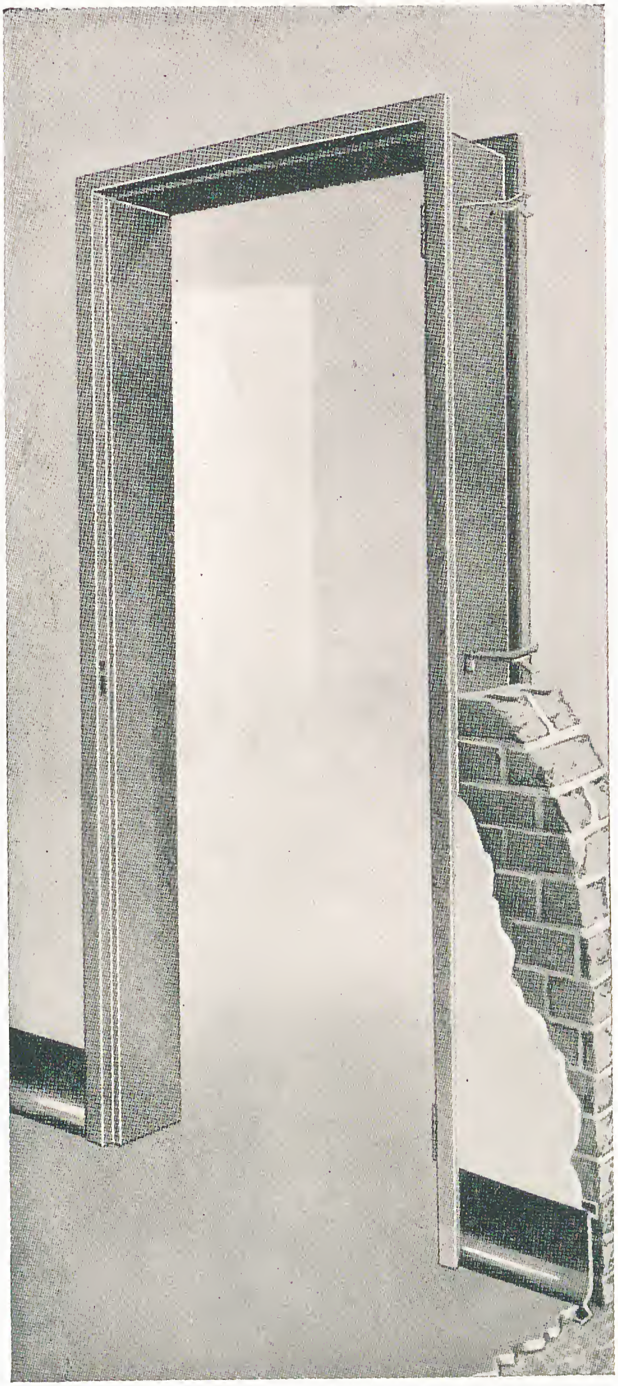


FIG. 173.—STEEL DOOR FRAME AND SKIRTING.
(Courtesy of Joseph Sankey & Sons, Ltd.)

designs are well suited to the plain style of modern work. It would, of course, be a big mistake to imitate the equivalent fittings in wood, since the nature of metal is quite different.

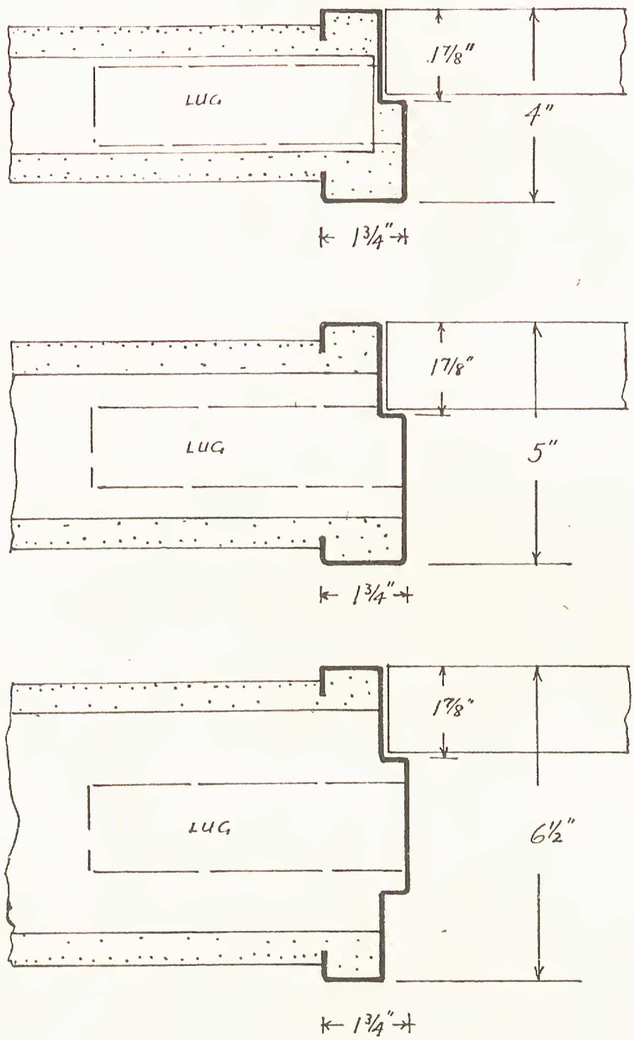


Fig. 174.—Standard steel door frames.

Metal trim is usually supplied with a priming coat applied at the works, but for metal sills and damp situations it is advisable to have the work rust-proofed.

CHAPTER 11

PLASTERING: SURFACES AND MATERIALS

Both in rendering on brickwork, stone, or concrete, and in plastering on laths, careful preparation of surfaces is essential to good work.

SURFACES TO BE RENDERED

When brickwork or stone masonry is to be rendered with coarse stuff the joints are often left unstruck, so that the protruding mortar may afford a key for the plaster. But as such protruding mortar will have dried before the rendering can be undertaken, it is far better to rake out the joints, so that the rendering may work into the joints and thus form its own key. Unless the bricks or stones have a rough-textured face the work will require hacking or roughing, otherwise there would be imperfect adhesion. This also applies to concrete. The surface must be brushed free from dust and dirt, and then well wetted before the cement mortar is applied, but prior wetting will not be necessary when a fairly moist lime plaster is being used, unless the brick is old and absorbent. Breeze concrete slabs present difficulties, as the joints must be given sufficient time to set and contract, and then it is not easy to wet the slabs sufficiently to overcome suction. The better plan is to skim the wet slabs as they are laid with a rich wash of Portland cement, which is roughened before it dries. Thus treated the slabs will take the plaster quite well.

FIXING LATHS

Wood Laths for Ceilings.—The laths have to be nailed to the underside of the joists, and should have a space of $\frac{3}{8}$ inch between each. Some specifications allow a space of only $\frac{1}{4}$ inch, but this is not sufficient for all but very small ceilings. The laths, which must be wetted before use, should be firmly nailed, taking care not to split the ends. These ends should form butt joints on the joists, close though not a tight fit, to allow for free expansion. It is necessary to break joint in order to lessen the risk of cracks. This breaking joint is often done in panels, but is better done with each alternate lath, by using alternately 3-foot and 4-foot laths. When joists are over 2 inches wide it is wise to adopt counter-lathing; that is to say, to nail laths along the joists, and fix the transverse laths to these. This ensures a better key for the plaster over the whole surface, and has the added advantage of lessening vibra-

tion. In some ceilings steel girders are found, supporting floors or walls above. Such girders are usually encased in metal lathing and cement mortar. Various methods are adopted to secure lathing to such encased girders, the best undoubtedly being to embed wooden nailing strips in the casing of the girders. Such nailing strips should be sufficiently substantial to take the place of joists. When heavy cornices are to be run pieces of wood must be cut to the profile of such cornices and fixed in the angles of the room, and at requisite distances at the junction of wall and ceiling, to serve as brackets to which laths can be nailed.

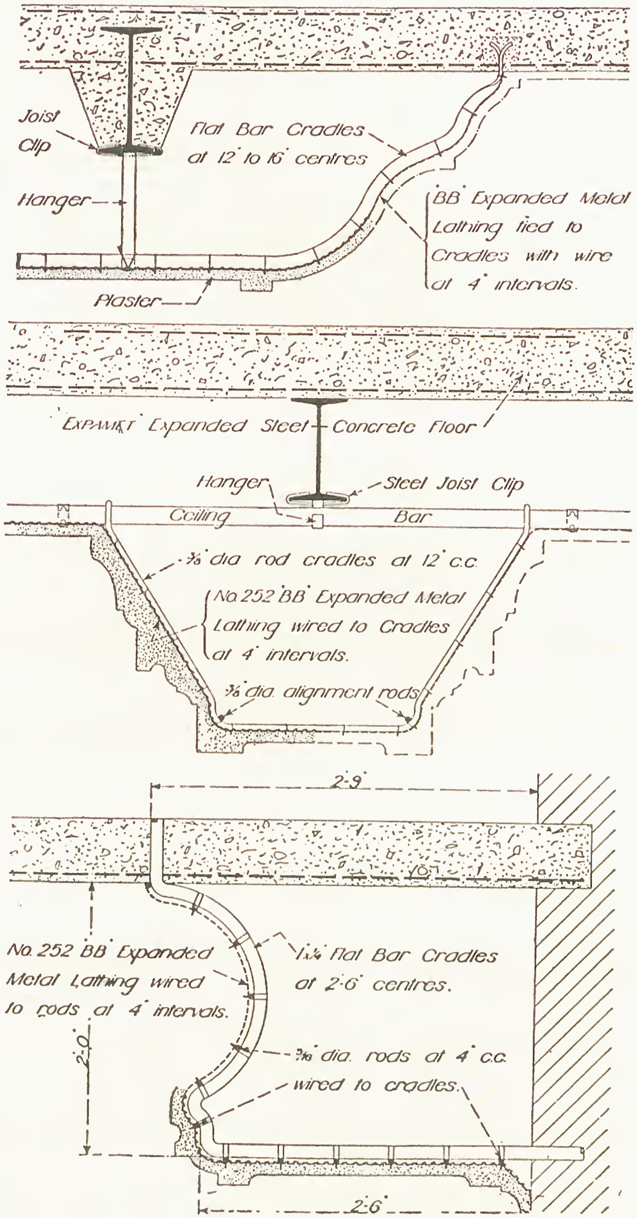


Fig. 175.—"Expamet" expanded metal lathing used to form false beams and moulded cornices.

Wooden Laths for Partitions. — No good plastering can be done unless the wood used for the studding is properly seasoned and of adequate scantling. A partition has not to support a great weight of plaster, but it has to resist shock and vibration, and if the timbers are too slight will be influenced by changes in temperature and moisture in the air. Before commencing lathing the framing should be plumbed and trued up where necessary. The spacing, unless the walls are very high or three-coat work is required, need not be more than $\frac{1}{4}$ inch; otherwise $\frac{3}{8}$ inch. Joints should be staggered as in ceiling work. Counter-lathing is advisable when large expanses are dealt with, or where considerable vibration is expected.

Metal Lathing.—Although no great skill is required, precautions are necessary when fixing metal lathing, as a faulty base means subsequent, and usually early, troubles. If the lathing is loose, the plaster is bound to crack, however well the scratch coat is applied. And there are other points to be observed. When fixing expanded metal to wooden supports, the sheets should be carried lengthways across the bearers, so that the long way of the diamonds or lozenges lies across and the strands of the sheets all slope one way. In fixing on a vertical face, the strands should slope inwards and downwards, which will prevent the first coat from sliding away from the lathing. Galvanised slice-cut staples will do for ordinary work, copper staples are to be used for better-class work and when the timber supports are of oak. Such staples should be 1 inch long for vertical work and $1\frac{1}{2}$ inches for horizontal (ceiling) work, being placed 4 inches from centre to centre for light lathing not above 3 pounds per square yard, and at 3-inch centres for heavier lathing. The sheets should be drawn taut, but care must be taken that the sheets are not distorted. This tautness without distortion is particularly difficult as regards wire-wove mesh. Sheets should be joined with a reasonable lap, and should be fastened by lacing, running galvanised wire through the meshes, or ties can be formed of short lengths of wire shaped like staples, the ties being laid sufficiently close together to prevent sagging. Joints should not be formed at corners, either vertical or where vertical and horizontal surfaces meet, but by bending.

Where the usual wood supports are not available, as in some frame buildings, especially when ribbed sheets are used over wide spans, wood fillets are embedded in the concrete when being poured round beams, joists, or stanchions, and to these fillets the lathing is fixed by means of staples. Such wood fillets, however, are apt to warp and separate from the concrete, which gives an uneven, insecure base for the lathing. Moreover, they are liable to attacks from dry rot. A better method is to replace the wood fillets by $\frac{3}{8}$-inch galvanised steel rods supported by $\frac{3}{16}$-inch hangers fixed to the girders, to which the lathing can be firmly laced. Occasionally girders and stanchions have flanges which can be drilled for hangers or lacing.

In the case of suspended ceilings, flat or round steel rods are suspended by hangers from joists or metal girders, and the metal lathing fixed to these rods by wire staple ties or by lacing.

MATERIALS

Modern developments in building construction, though multiplying methods of wall and ceiling finish, have not, on the whole, lessened the importance of the plasterer's trade. There is, indeed, a call for greater attention than ever in this difficult branch of the industry, partly owing to the progressive lessening of time allotted to the various operations and partly because of the increasing diversity of materials used both as a

base and for rendering. This, calls for constant variations in handling.

As a result of the introduction of these new materials it is necessary to consider the constituent parts of plasters (mainly limes, cements, and sand) in relation to the uses to which they are to be put and also the base to which they are to be applied. Plasters have not, as a general rule, to resist crushing strains, but in many positions resistance to tensile stresses is very important, while in other cases relative porosity, or again resistance to moisture, is chiefly aimed at.

Lime.—Lime is derived from many sources, usually in blocks or lumps. These are burnt in a kiln to drive out most of the moisture and carbonic acid contained in the rough material. It then becomes caustic lime. This must be slaked in pure water, about 32 per cent. by weight of the lime being required for this purpose. This is usually done in a mortar box, or for large quantities in a pit, the sides and bottom protected by planks, on a platform within a ring of sand or on a base of sand with a ring of sand round it. The lime and water has to be well stirred to break up the lumps. It swells, becomes hot and throws off steam. Stirring must be continued until little steam arises. It may then be left alone, when it gradually dries. For plastering purposes the slaking must be very thorough, all lumps being broken up during the process. If this is not done some caustic lime will remain, which in the plaster absorbs moisture from the air, causing "blowing," the blisters resulting in cracks and disintegration. To ensure perfect slaking after the first process the lime is broken down and once more mixed with more water to form a thick cream, which is allowed to stand for from two to four weeks to "cool." This long running produces what is known as "plasterers' putty."

Fat or rich lime, also known as pure lime and chalk, is produced from layers of the upper chalk or other beds containing from 95 to 99 per cent. of carbonate of lime. It slakes rapidly, with great heat, swelling to twice or thrice its original bulk. It works smoothly and easily, improves by being mixed some time before being used, but lacks strength. It is essentially for interior and fine work.

Poor lime, containing between 60 and 90 per cent. of carbonate of lime, part of the inert matter being clay, slakes slowly, does not greatly increase in bulk, hardens well, but lacks strength. It is suitable for exterior work of a rough kind.

Hydraulic limes are those produced from stone in which a high percentage of carbonate of lime is associated with clay containing silicate of alumina. The lias or blue lias limes belong to this class. They are feebly hydraulic if containing not more than 10 per cent. of silicate of alumina, ordinarily or medium hydraulic if over 10 and under 20 per cent., and strongly hydraulic if up to 30 per cent. Such limes are only suitable for exterior rendering in positions exposed to water.

Gypsum.—Gypsum, calcium sulphate, which is produced from gypsum rock, is considerably heavier than both chalk and limestone. Under ordinary conditions it swells greatly and sets rapidly, but has little

strength. It forms the basis of several plasters and cement, but is best known under the form of—

Plaster of Paris, which is produced by burning and slaking the gypsum rock. It is chiefly used for mixing gauged stuff, for moulding cornices and other ornaments, and for small repair work, such as filling cracks.

GYPSUM AND ANHYDRITE PLASTERS

Plasters prepared from calcium sulphate hemihydrate (plaster of Paris or calcined gypsum), and anhydrous calcium sulphate, are now widely used for finishing coats and undercoats. They are sold under various trade names or brands. The characteristics of these plasters differ, even in the same class, so both the class and the brand should be understood. There are five classes in B.S. 1191. They are:

Class A.—Plaster of Paris or "gauging plaster." This sets very rapidly and is used in the neat state for repairs only. It can be gauged with lime for finishing coats. But it is now usual to use one of the following classes for such work. Plaster of Paris should not be retempered.

Class B.—Retarded hemihydrate gypsum plaster, marketed under many proprietary names, is basically plaster of Paris with a retarder added to give a longer period between adding the water and the commencement of setting. But when setting starts it proceeds rapidly and the plasterer must work quickly. Undercoats are gauged with sand or lime-sand coarse stuff. Finishing coats are used neat or with lime. Class B plasters should not be retempered after the initial stiffening.

Class C.—Anhydrous gypsum plaster, based on anhydrous calcium sulphate, may be used neat or with lime or coarse stuff. These plasters can be retempered up to 1 hour after mixing.

Class C plasters are made in three types—undercoat, finishing coat, and dual-purpose. Some are not suitable for application to plasterboard.

Class D.—Keene's or Parian plasters are also divided into three types —undercoat, finishing coat and dual-purpose. The widest use for this class is for finishing coats when they are used neat. These plasters may be retempered up to 1 hour after mixing. Some types may be used with lime, and some are not suitable for application to plasterboard.

Class E.—Anhydrite plaster, a dual-purpose plaster for both undercoats and finishing coats, and for single-coat work on boards. Lime should not be used, but for undercoats 1 part plaster is mixed with $1\frac{1}{2}$ parts sand. This plaster may be retempered up to 1 hour after mixing.

Owing to variations in the processing of different brands the manufacturer's instructions should be carefully read and followed. In case of doubt where special circumstances exist the makers should be consulted.

Plasterers like to work with one brand of plaster only, as they then become expert in its use under all conditions. But as architects specify particular brands it is obviously desirable for plasterers to widen their experience, and when called upon to use an unfamiliar plaster to study the maker's instructions before starting work.

Uses.—The chief points to observe in selecting and using gypsum and anhydrite plasters are as follows:

Class B, retarded hemihydrate plasters, set quickly and should be allowed to dry as soon as possible.

Classes C, D, and E, anhydrous calcium sulphate plasters, set not so quickly and should not be allowed to dry quickly, though dampness for an excessive time is undesirable. Keeping damp for forty-eight hours is usually adequate for complete setting, though the maker's instructions should be consulted, as the requirements of the various brands differ. If plasters of this type are allowed to dry too quickly trouble may be caused later by expansion in a damp atmosphere, and cracking and flaking may occur.

Lime and sand should be used only in strict accordance with the instructions given by the makers. Lime should not be used with Class E plasters. Portland cement should not be mixed with any class of gypsum plaster, though Class B plasters can be applied to cement surfaces.

Plasterboard and fibreboard are now widely used on ceilings and partitions, and are usually finished with one skim coat of plaster. Class B plasters should be used for this purpose, and a low-setting expansion type is specially made so that risk of cracking is reduced to a minimum.

Hardness.—Gypsum and anhydrite plasters are hard and dense compared to lime plasters, though those plasters suitable for a lime admixture in the finishing coat can of course have the natural hardness modified to a limited extent.

The order of hardness increases as follows: Class B, Class C, Class D, Class E. Class B plasters are the most widely used for general work. Where hardness is specially required, Class D, Keene's or Parian, may be used.

It is the custom to refer to retarded hemihydrate (Class B) plasters as "hardwall plasters," no doubt as a comparative term to distinguish them from the softer lime plasters. The term is a loose one and it is better to refer to the particular class of plaster, in accordance with the B.S. 1191 descriptions.

All gypsum and anhydrite plasters can be trowelled to a very smooth and dense finish, but this is not always desirable. A slight texture on the surface gives better adhesion for wallpaper and paint. And the more glassy the surface, the greater the tendency to condensation, and also to sound reverberation. The latter trouble has led to the use of so-called Acoustic plasters, which usually consist of a Class B plaster with a special aggregate or a foaming agent which produces a porous plaster, tending to absorb sound. These plasters cannot be given a smooth finish and are easily damaged, so they are better suited to ceilings and the upper part of walls.

Heat and sound insulation of walls are not much affected by the type of plaster, owing to comparative thinness of the plaster.

SAND

Sand must be clean and should comply with B.S. 1198. Sand is usually mixed with gypsum and anhydrite plasters for undercoats, but it reduces

the strength. A mix of 1 part plaster to between 1 and 2 parts sand is usual. Sand should not normally be used in finishing coats, except for gauging lime finishing coats.

Sand for undercoats should be moderately sharp but well graded from fine to coarse. For smooth finishes fine sand is necessary.

HAIR

Cow hair or fibre should be mixed with plaster undercoats for application to lathing. It reduces droppings to a minimum and helps to hold the plaster until it sets. Hair can be mixed with plaster on the site, though plasters ready haired are now marketed and widely used. The usual admixture is 1 lb. of hair or fibre to 2 or 3 cubic feet of undercoat mix. Hair is not used for gypsum and anhydrite finishing coats.

LATHS AND LATHING

Wood Laths.—Wooden laths are of oak or fir. Oak is the stronger and more durable, but it is also the most liable to warp and to stain. They may be riven or sawn. The riven, being split from the log, consequently with the grain, are stronger; sawn are more even, but being often sawn across the grain, are weaker. They are cheaper and quite suitable for most partition work; for ceilings, especially if extensive and heavy, riven are to be preferred. They are sold in three sizes: (1) "single," average $\frac{1}{8}$–$\frac{3}{16}$ inch thick; (2) "lath and a half," average $\frac{1}{4}$ inch thick; and (3) "double," average $\frac{3}{8}$–$\frac{1}{2}$ inch thick. They are about 1 inch wide and from 2 feet to 5 feet long (usually 3–4 feet long), and are made up into bundles containing 360–500 feet.

Single laths can be used for light partitions and quite small ceilings; but for average ceilings lath and a half are needed, and for large, heavy ceilings and partitions with widely spaced studding and carrying heavy coats of plaster, double laths. Laths should be straight, free from knots and sap. "Sap" (which includes resin) denotes imperfect seasoning of the timber, and therefore may lead to decay as well as staining.

For fastening, nails are required. They should be wrought, with clout-heads, $\frac{3}{4}$ inch long for single laths, 1 inch for lath and a half, and $1\frac{1}{4}$ inches for double laths. Ordinary iron nails are sometimes used, but it is wiser to have them galvanised, and for oak laths either zinc or copper. On an average 500 nails are needed per bundle, calculated to cover 5 square yards with $\frac{3}{8}$ inch space between the laths.

Metal Lathing.—Expanded metal and proprietary metal lathings are now widely used instead of wood laths.

Metal lathing, well selected, carefully fixed, and reasonably applied, possesses many advantages. Sound riven oak laths will last for centuries, as experience abundantly proves. Now, however, they are expensive and difficult to obtain, while the sawn type of lath, especially if of fir, is not so reliable. Metal varieties, as a rule, give more strength and better security as regards durability, for with proper precautions they can be

made rust-proof, provide a good key, an appreciable resistance to the spread of fire, and do not harbour vermin. Moreover, metal lathing is easily bent to different shapes, which is of great importance in the construction of ceilings designed on different planes: those of vaulted or curved type, with curved cornices or exposed beams; in the formation of partitions, panels, pillars, casings for columns, and so on. Thus metal lathing in one or other of its many forms is very useful, not only in the construction of partitions or ceilings, but also for the heavier panels in framework buildings. Success, however, is not always secured, which arises from one or more of several causes. In most of the expanded metal or wire-woven sheets the mesh is sufficiently wide to afford an excellent key. But in order to secure such a key the mortar must be of a proper consistency; it should be fairly stiff but plastic. A wet mortar, or plaster, is not so necessary as it is when rendering on wood laths, as the metal, unlike wood, is non-absorbent, and so does not rob the plaster of its needed moisture, it should, however, be soft enough to find its way easily through the mesh, and plastic enough to spread out and form a mushroom head on the reverse side. It should be remembered that good work on metal lathing will always require an extra amount of mortar for the under coat, as more of it should be pushed through the mesh. This does not apply so much to the wire mesh as to expanded metal. If the mortar is too wet it will be troublesome in floating, because it is apt to slide down, though far more by producing a thin, unsubstantial dribble at the back. But a too-dry mortar will be hard to work through the mesh, will not spread out well at the back, and will provide a weak key, because it is brittle and more apt to crumble than set into a hard mass. The strong, lasting key, not liable to shear off, can only be obtained with a plastic mortar which will spread out both back and front. For this reason a straight, quick-setting cement mortar is not advisable for the under coat on metal lathing; there should always be a small percentage of lime—preferably hydrated lime. This will prevent the mortar being crumbly, and will ensure better adhesion. It should, however, be borne in mind that cement mortar (with this small addition of lime) is better for the base coat than a pure lime mortar, as the coefficients of expansion and contraction of cement and steel are more closely comparable than that of lime mortar and steel, so the percentage of hydrated lime should never be more than 10 per cent. by volume of the dry cement.

Types of Metal Lathing.—Discretion must be shown in the selection of metal lathing or base according to the work in hand. While wire netting is perhaps the most flexible type, specially adapted for ceilings, light panels, and for casing small pillars, it requires great care in fixing and in applying the mortar, because it is more apt to sag than a more rigid type, and in any case does not give a very strong key. If a sheet of wire netting is not thoroughly stretched, there will be unevenness of surface, with risk of cracking and disintegration. The wire-woven mesh is the best, though for cheap work, if reinforced with steel bars, ordinary

galvanised netting of small or medium gauge can be used for many purposes other than ceiling work. Where greater strength is required, metal laths, or perforated and expanded steel sheets, should be used. The type most favoured for general work is the diamond-mesh expanded sheet. This gives a fairly rigid base, while the slits in the metal provide security for a strong key. Where still higher rigidity is desired, particularly in panel and partition work, there are more rigid perforated sheets. While for covering wide bays between supports and with a view to economising the metal framing for the supports, there are expanded slit sheets with hollow or solid rib reinforcement. The space between the hollow ribs ranges from 3 inches to 4 inches, and between solid ribs 1 inch to $1\frac{1}{2}$ inches; the space between the ribs is filled with expanded mesh. It may be mentioned that one form of solid base occasionally consists of ordinary corrugated galvanised sheets. But this gives a very poor key, even when the sheets have been treated with special "sanded" paints, and such a base is only suitable for very cheap garden walling, or for forming sunken tanks or the bottom and sides of ponds.

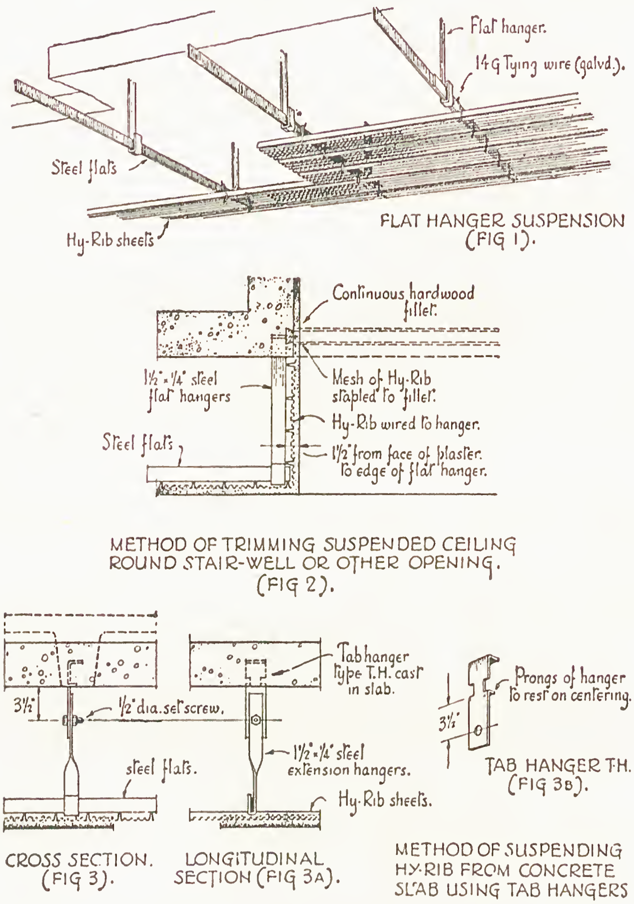


Fig. 176.—"Hy-rib" suspended ceilings. The ribs, which are pressed in the sheets, stiffen the ceiling and allow bearers to be widely spaced.

Expanded Metal is made in two forms: in "BB" or lozenge mesh, and in diamond mesh; the first in $\frac{3}{8}$-inch thickness and the second in both $\frac{3}{8}$-inch and $\frac{1}{4}$-inch thicknesses, the gauge of the metal varying from 20 to 26, the sheets measuring from 9×2 feet to 6×2 feet. A 9×2-foot 26-gauge "BB" mesh sheet weighs $2\frac{1}{2}$ pounds, and a 6×2-foot 20-gauge $\frac{1}{4}$-inch diamond mesh sheet 5 pounds. This latter form is best when plaster is used without hair. This expanded metal is easily bent to any shape, yet is sufficiently rigid, so is suitable for a great variety of purposes, in-

cluding ceiling and partition work, as well as column and other casing.

B.R.C. Fabric is a sound, flexible, woven base, the wires of the mesh being electrically woven at their intersections. It is largely used for ceiling and flooring work.

Hy-Rib consists of steel sheets, 28, 26, and 24 gauge, slit in such a way that a herring-bone pattern is formed in three strips with plain ribs between them. They are 12 feet long and 12 inches broad, made to interlock at ends and sides. The slots provide an excellent key. Hy-rib is particularly useful for suspended ceilings and partitions with considerable spans. It is light in weight and sufficiently flexible to form barrel ceilings, columns, etc.

Self-Sentering is a strong lath of the ribbed type of expanded metal. The ribs are connected by a diamond mesh of expanded metal. The stiff ribs of steel sufficiently explain the name of this lathing and its handling. It is claimed to economise timber and labour. It is used for all kinds of purposes, but chiefly for floors, roofs, tanks, and sanitary work, such as sewers, culverts, air-ducts, etc. Its ribs are hollow, of a V shape, so give a good key, like the mesh.

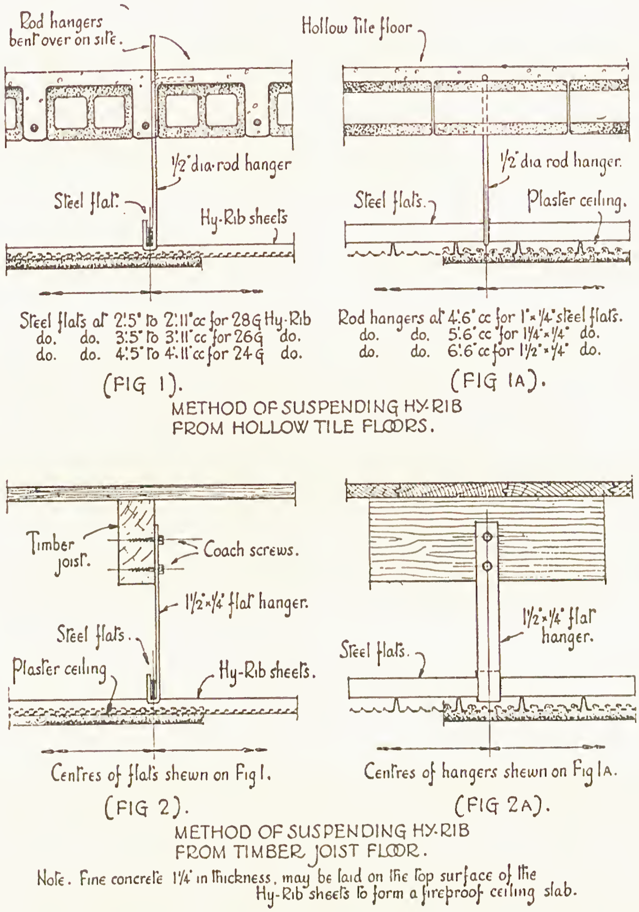


Fig. 177.—" Hy-rib " suspended ceilings.

Trussit, like the above, is made by the Self-Sentering Expanded Metal Works, Ltd., and is rather similar, but is made up of corrugated expanded steel sheets, the crest and base of each wave being flat and joined together by "herring-bone" mesh. Owing to its pattern, it forms a rolling key, the plaster encasing and interlocking with the lath, so guarding against the risk of falling plaster. It is suitable for sound-proof fire-resisting partitions, lift-enclosures, garages, boundary walls, and so on. Quite an efficient partition may be no thicker than 1½–2½ inches. "Trussit"

is made in sheets 19 inches wide, up to 12 feet in length, and in three gauges, 28, 26, and 24.

Bricanion is quite a different type of lathing, consisting of steel wire netting encased in a series of small burnt-clay crosses with chamfered sides. The crosses closely touch each other but are independent; thus the lathing can be bent to any required form, and is as suited for rectangular pillar or rounded column work as it is for ordinary partitions. A perfect key is provided. Cutting to required sizes and jointing up are both easy, as the clay crosses can be broken off, the exposed wires either cut with a special snip or tied together as the case demands. For partitions $\frac{5}{16}$-inch reinforcing rods are used, placed vertically and horizontally 20 inches apart. For ceilings the lathing is supported by $\frac{5}{16}$-inch stretching rods, inserted into cramps at 12-inch intervals; this, on large ceilings, being supplemented by 14 S.W.G. galvanised wires tightly stretched across the joists.

Treatment of Lathing.—Durability of good plastering depends very largely on the behaviour of lathing under ageing. If wood laths are liable to warp and decay, steel is very apt to rust, and by scaling or blistering not only weaken the base, but destroy the key and attack the plaster. To avoid this, metal lathing is generally galvanised. This is unavoidably an expensive process, because to be effective it must be carried out thoroughly and after manufacture. A single spot left unprotected by the spelter may form a weak place where corrosion may begin and go on behind the protective coat. That is why many prefer protecting the lathing with a dressing of bitumastic paint.

Some interesting points on this side of the question were brought out by a series of tests inaugurated as far back as 1925 by the Michigan Engineering Society's experimental station, and reported upon in 1931. The experiments were directed to determine the effects of weathering on bases, such as metal lath and wire-wove fabric rendered with Portland cement mortar and specially prepared stucco. For this purpose 3-foot square panels were constructed of sheathing boards 6 inches wide dressed on both sides to a uniform thickness of $\frac{13}{16}$ inch, placed horizontally and securely nailed to studding placed 17 inches from centre to centre. Heavy tarred paper was placed over the sheathing for purposes of insulation, and the metal lathing held away from the tarred paper by means of $\frac{3}{8}$-inch firring slips attached to the sheathing by 1-inch large-headed galvanised roofing nails at points 6 inches each way, lapped 2 inches at sides and each end. Vertical and horizontal laps were fastened by galvanised staples $1\frac{1}{4}$ inches by 14 gauge, not more than 8 inches apart. Two kinds of plaster were used: (1) a mix of 1 part of Huron Portland cement and 3 parts of sand graded from fine to pass when dry through a No. 8 screen; (2) Rocboard stucco; a proprietary compound consisting of magnesite, silica (ground to powder), ground cork, asbestos fibre, and sharp sand for the first coat, and magnesite, silica, and white silica sand for the top coat, both tempered with magnesium chloride.

In both cases two coats were applied—the scratch, or base, coat $\frac{1}{2}$ inch thick, well laid on by thorough trowelling. Before actually set, this coat was heavily cross scrubbed with a stiff brush, the surface kept damp, and the top coat, $\frac{3}{8}$ inch thick, applied the following day and finished with a steel darby.

The reinforcements, or bases, were a hollow-ribbed lathing weighing 3·4 pounds per square yard, zinc-coated galvanised metal lathing weighing 3 pounds per square yard, and galvanised wire-wove 2-inch mesh, weighing 2·8 pounds per square yard.

After four years' exposure in the open air part of the plaster was removed from the edge of each panel by means of a light hammer, and later a larger piece from the middle of each panel. It was found that galvanising was more satisfactory than painting, both as regards adhesion and condition of the lathing. With Portland cement the best results were obtained with 2-inch mesh wire-wove fabric, galvanised. Portland cement on the hollow rib lathing, painted, did not give sufficient protection of the lathing, being partly broken, especially near the edge, though the surface was fairly satisfactory, the plaster showing only small cracks. Portland cement on galvanised metal lath expanded metal sheets was not satisfactory; while the lathing remained intact, it rusted in spots and rust had apparently pressed out the mortar. It was thought that owing to difference of the coefficients of expansion between the cement and the steel cracks had occurred which permitted moisture to penetrate and corrode the base. The patent stucco did badly on painted hollow rib metal lathing, the reinforcement being broken at both edge and centre, while the surface was heavily cracked. On galvanised expanded metal sheet the patent stucco did very well, the lathing being well preserved and the surface in fine condition.

PLASTERING ON PLASTERBOARD AND FIBREBOARD

The use of plasterboard as a form of lathing to take either two coats of plaster or a single skim coat has spread widely in recent years. To a less extent low-density fibre building board is also being used for the same purpose. Not all types are suitable, and when ordering it should be stated that the material is wanted for an applied plaster finish.

As both plasterboard and fibreboard do not provide a mechanical key, but depend upon surface adhesion, plasters which adhere strongly must be used. Special "Board" plasters of gypsum and anhydrite are marketed and it is advisable to use these. If a Class B gypsum plaster is used it should be of a low-setting expansion type. Class E, anhydrite, plaster is suitable. No lime should be added to the plasters applied to boards. In two-coat work the undercoat may be sanded. A skim coat should be neat.

The joints should be prepared according to the instructions issued by the makers. Usually the joints are covered with fabric scrim bedded in plaster.

Adequate fixing is essential to prevent the boards bending or moving, especially to fibreboard, which needs plenty of intermediate support.

CHAPTER 12

PLASTERING: EXTERIOR AND INTERIOR

EXTERIOR work is now called rendering in preference to the older name of stucco, and it is usually carried out in Portland cement instead of the older hydraulic lime.

The term plastering is now reserved for interior work on walls, partitions, and ceilings. Lime is used for the under coats, but the finishing coat is usually a gypsum or other hard plaster.

EXTERIOR RENDERING

Exterior rendering with either a smooth or roughcast finish may be applied, with the object of covering an inferior-looking walling material, or to give the wall extra resistance to the weather.

The Wall Face.—As renderings are often applied to cheap common brickwork and as a means of renovating decayed walling, we must first carefully consider what is essential in the condition of the wall face if trouble is to be avoided in the rendering.

There are two chief requirements: the wall face must provide a good key to enable the rendering to adhere, and it must be mechanically and chemically stable.

If the walling material has a smooth dense surface, raked joints may not provide an adequate key, and it will be necessary to punch the surface all over to roughen it. It is advisable to give most of the punched depressions a slight undercut, so that they form an effective key. Ordinary brickwork with a slightly rough and absorbent surface does not need further treatment provided the joints are well raked and then washed and brushed with a stiff bristle or wire brush. The whole of the surface must be clean and free of dust, soot, and efflorescent salts. Any decayed bricks should have the loose surface cut away.

If the walling generally is in bad condition with the surface spalling off, and on cutting the loose work away it is found that the interior is soft and unreliable, it is advisable to cover the wall with expanded metal or ribbed metal lathing wired to steel rods, which should be stapled to the wall. Trouble will certainly follow if rendering is applied to a wall surface which is disintegrating.

Efflorescent salts present in the walling may cause trouble by forcing the rendering off the wall face. If there is much efflorescence the wall should be lathed with expanded metal as just described.

Rendering Mixes.—The old stucco mixes consisted of 1 part hydraulic lime to 3 parts sand, with 1 lb. cow hair to the cubic foot of stuff. It was necessary to protect this stucco with oil paint. Modern rendering consists of a Portland cement and sand, or a Portland cement-lime-sand mix.

A Portland cement mix is strong and dense but tends to crack or craze through creep and shrinkage. A cement-lime mix is not so liable to give trouble. The Building Research Station recommend the following:

Under Coat (parts by volume):

3 parts white hydrated lime or stiff lime putty.
1 part Portland cement.
10 parts clean sand or crushed stone aggregate.

Finishing Coat:

3 parts lime, as above.
1 part Portland cement.
12 parts sand or crushed stone, according to colour and texture required.

The materials can be mixed mechanically or by hand. If lime putty is used this may be knocked up into lime-sand coarse stuff, and the cement added before use. All material should be used up within about two hours from the time when the cement is added.

Where the exposure is exceptionally severe, it is advisable to use a cement-sand mix for the under coat.

If the rendering is applied as a cure for dampness the under coat should be waterproofed (see Chapter 8, Vol. II).

Surface Finishes.—The grey colour of normal Portland cement is not attractive. White or tinted cements can be used, or the normal cement rendering can be treated with a colour wash or a cement or stone paint.

A smooth finish produced with the steel trowel shows up any crazing, and it may be mentioned that over-trowelling brings a rich cement film to the surface which is more liable to craze than the weaker body of the mix. Rough-textured finishes conceal crazing to all but very close inspection. A wood float can be used to produce a rough finish. Patterned and scratched finishes can be easily produced by using wood combs and tools.

If it is desired to preserve a clean surface, a white or colour wash, or a cement or stone paint, should be used as a finish. This is certainly preferable in a polluted atmosphere where light-toned surfaces are rapidly soiled.

RENDERING WORKMANSHIP

When the surface has received its appropriate preparation, the wall is divided up into vertical bays by fixing dots (nails or pegs) representing depth gauges to the exact thickness of the coat desired. These dots are connected up by lines, or twine, which must be accurately plumbed, and

then vertical screeds run as gauges. These should not be wider than 3 inches, and must run from the top of the wall (below the lowest member of cornice, if any) to the bottom; but this can be done in convenient sections of say 6 feet in height, if plumbing is carefully attended to. The running of the screeds, however, must be from top to base, and it is in this order that the floating must be carried out, as soon as the screeds are hard enough to bear the rule which has to be applied to secure evenness of the finished surface. The plaster is applied with the mortar, gauged with the rule run from screed to screed, and smoothed with a wooden float. Care is particularly needed in joining up to the screeds and the different sections of the bays. This is all that is necessary with ordinary rendering.

Finishing.—Finishing, also termed fining, consists in applying a top or finishing coat, adopted in two-coat rendering and in three-coat stucco work. When the rendering coat is set it is scored over and thoroughly wetted prior to applying the finishing coat or coats. As a rule the rendering coat is $\frac{1}{2}$ inch to $\frac{3}{4}$ inch thick and the fining coat $\frac{3}{16}$ inch. Or in three-coat work the respective thicknesses should be $\frac{1}{2}$ inch, $\frac{1}{4}$ inch, and $\frac{3}{16}$ inch. It is necessary to use the feather-edge or short rule in finishing off reveals and arrises at angles, windows, and door openings, etc.

Moulding and Cornices.—Mouldings forming string courses round panels, window, or door openings, will require separate dots and templates if of complicated outline. Cornices are also run by means of templates cut to pattern.

Special Cements.—Special cements, such as Keene's, are occasionally, though rarely, used for rendering. More often their use is restricted to running of cornices or other ornamentation. This calls for no remarks here, other than to observe that their use for such purposes calls for extra care and quickness of work, particularly in hot, dry weather.

Jointing.—Many rendered and stuccoed façades are finished off in imitation of stone masonry. This may be done all over the surface or merely at the angles. For this purpose rods should be marked off to give the horizontal and vertical gauges, and lines are snapped by means of a chalked line. The actual jointing requires two men to work together, as a rule, or feather-edge, has to be held against the line and the joint marked out with a jointer, an S-shaped iron tool. The jointing may be plain or rebated. When rebated, unless the work is to be painted, some touching up with the fining stuff may be required in a deep, broad rebate.

ROUGHCASTING

Roughcasting is often adopted as a decorative finish, though a rough-textured rendering is now generally preferred. Roughcasting can be applied to new work or as a remedial measure in the case of old weather-beaten brick walls. Roughcast may vary almost indefinitely. A commonly used mixture is made up by volume of 1 part of hydraulic

FIG. 178.—AN EXAMPLE OF MODERN PLASTERWORK (PIONEER PLASTER) AT THE GAUMONT PALACE CINEMA, WOOD GREEN

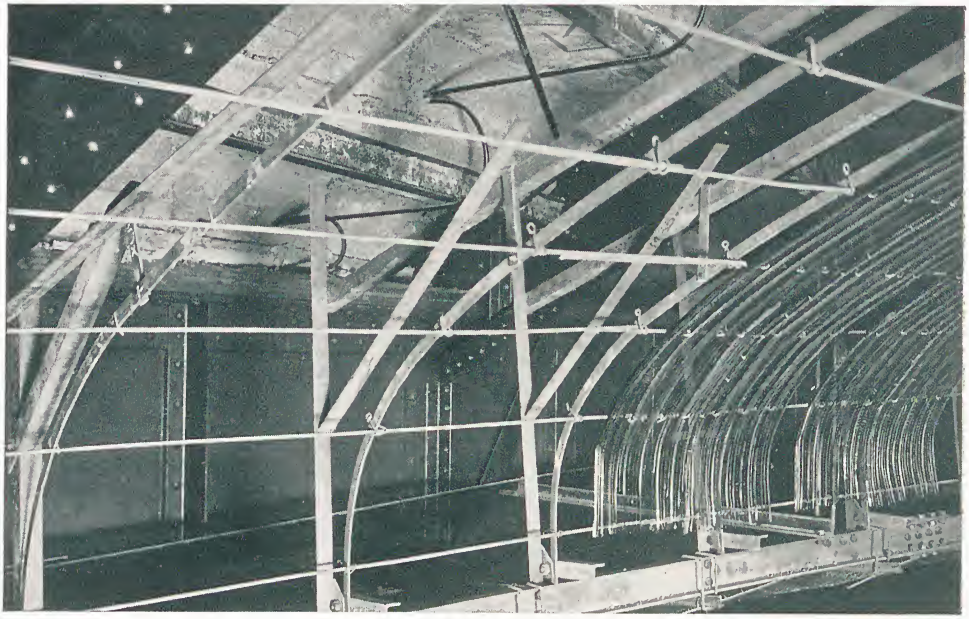


FIG. 179.—SELF-SENTERING EXPANDING METAL USED IN THE CONSTRUCTION OF AN ELLIPTICAL DOME AT THE LEICESTER SQUARE THEATRE, LONDON. (For Battiscombe & Harris, Ltd.)

FIG. 180.—SELF-SENTERING EXPANDED METAL CURVED TO FORM BALCONY STEPPINGS AT A CINEMA.

lime, 1 part of fine sand, and 2 parts of either coarse sand, stone chips, flint scalings, broken hard brick, or crushed gravel. Better mixtures are made up as follows: (1) 1 part of Portland cement (to which is added 3 per cent. of a good waterproofing material), 1 part of washed fine sand, and 2 parts of any coarse aggregate such as mentioned above; (2) 1 part of Portland cement (with 5 per cent. of waterproofing material), 1 part of washed sand, and 1 part of granite chips, flint flakes, or crushed gravel. Earth colours can be added for tinting, though often the aggregate will provide all that is needed in this way.

Before application walls must be brushed down to remove dust and loose particles and then well wetted. Roughcast with sand and fine aggregate can be applied with the trowel, but left rough. When the aggregate is too coarse for this, however, a rendering of the coarse stuff, about ½ inch thick, must be applied rather moist, and the coarser aggregate, soaked in cement wash, dashed on with an iron scoop. The aim is to secure even distribution of the coarse aggregate, and sufficient force must be used to cause the aggregate to penetrate into the coarse stuff.

Pebble Dash and Depeter.—A special form of the above is known as *sand* or *pebble dash* or *harl*. The wall receives a rendering of coarse stuff ½ inch thick, applied roughly with the trowel, and against this coarse sand or pebbles are dashed by means of a scoop. In *depeter* small stones, pebbles, or flints are pressed by hand into the moist rendering coat. In this way simple or quite elaborate patterns can be formed and a durable weatherproof finish obtained.

INTERIOR PLASTERING

Interior plastering is a many-sided craft, for it includes the dressing of plain surfaces and the building up of decorative details, such as mouldings, cornices, embellished ceilings, and other elaborate work. Moreover, the treatment of plain surfaces will differ according to whether they are to be papered, distempered, painted in oil colours, or otherwise finished. Other problems have to be considered, such as the base to be plastered, questions of acoustics and dampness, and the plaster modified accordingly. Certain of these points have already been touched upon when dealing with materials, others will be discussed in the course of describing operations.

After the selection of materials the next important consideration is that of mixtures.

MIXTURES

A great many kinds of plasters are used, apart from the special and patent cements, the principal mixtures being given below. In all cases the ingredients should be thoroughly mixed, while dry, and in most cases only gauged just before use. Most plasters are not improved by re tempering and knocking up when once dry, and some are entirely spoilt thereby.

The mixtures most commonly used are:

Coarse Stuff.—This is composed of 1 part of slaked lime, 2 to 3 parts of sand, crushed slag or brick, and from $\frac{1}{2}$ to $\frac{3}{4}$ pound of ox hair to the cubic foot. It is used for the rendering or base coat.

Gauged Stuff is a compound of 3 to 4 parts of lime paste to 1 part of plaster of Paris, or of coarse or setting stuff with plaster of Paris in the ratios of 3 to 1, 2 to 1, or 1 to 1. It is used in second-coat work, and in its finer type for moulded work. It should contain hair.

Fine Stuff is made up of 3 parts of lime paste and 1 part of fine sand, without hair. It is used for the floating coat in three-coat work and as the finish in two-coat work.

Setting Stuff, or *Plasterers' Putty*, is also made with lime paste and a very little fine sand, both passed through a hair sieve before mixing. This is usually the finishing coat.

Cement Plaster is made up of 1 part of powdered quicklime, 1 part of powdered baked gypsum, and 4 parts of powdered baked clay. The quicklime and gypsum are mixed separately with half each of the clay, and the two mixed together and well stirred to ensure slaking of the quicklime. The stuff is gauged with glue water just before use. It is useful for rendering on rough walls and positions likely to suffer from dampness.

Fancy Setting Stuff.—Setting stuff may have sifted marble dust added to it, which makes it finer, much harder, and enables it to take a high polish. The addition of ground glass or carborundum powder gives it a sparkling finish. Colour, and strength, can be gained by adding finely ground brick, slag, or forge ashes. A grey hue is obtained by adding a mixture of marble dust and ashes; blue with a mixture of 2 parts of marble dust, 1 part of lime, and $\frac{1}{2}$ part of oxide or carbonate of copper; green with marble dust and green enamel; reds with red oxide of lead.

Other plasters are used for special purposes.

Stucco.—Stuccoes for ordinary exterior work have already been described, but there is also *Stucco Duro* or *Modellers' Stucco*, which is very suitable for modelled and moulded work. It is made up of equal parts of fat slaked lime and finely powdered white marble, gauged with lime water. Stucco for fresco and fine oil painting is usually made up with 2 to 4 parts of washed silver sand, 1 part of lime putty gauged with lime water. A mixture of 2 parts of marble dust and 1 part of lime putty is also excellent for the purpose.

Gesso is also used for fine modelling as well as being used after the manner of plastic paint. The two following recipes give good results: (1) 1 part of powdered resin, 4 parts of linseed oil, 6 parts of melted glue, and powdered whiting according to consistency required. The oil, resin, and glue are boiled in a water bath, and the whiting, previously soaked in pure water, is added to the mixture while hot but off the boil; (2) mix plaster of Paris, linseed oil, and melted glue to form a flowing paste.

Compo Pastes.—(1) Take $2\frac{1}{2}$ pounds of best glue, 2 pounds of resin

and 1 pint of linseed oil. Mix together and roll out, using sifted dry whiting to prevent sticking. (2) Take 3 pounds of Scotch glue, ½ pound of resin, ½ pint of raw linseed oil, ¼ pint of boiled linseed oil, ¼ pound of Burgundy pitch, and ¼ pound of Venice turpentine. Soak the glue in hot water and melt in a hot-water bath, mix in the oils, turpentine, and pitch. Mix and roll out on a metal or marble slab. It is improved by hard kneading, using sifted dry whiting. Useful for modelling and moulding where fine details are required.

Mastic is a compound of powdered marble or white stone and silver sand, in the ratio of 2 to 1. When well mixed about ¼ part of vitrified lead, or a mixture of copper and silver sand, with an equal amount of red lead, is added. It is gauged when wanted with equal parts of raw and boiled linseed oil. Used for mouldings and also for filling joints between windows and door frames and walls.

Scotch Mastic, used for the same purposes as ordinary mastic and formerly also as a finishing coat, is prepared with 14 parts of powdered sandstone, 3 parts of whiting, 1 part of litharge, and a sufficiency of raw or boiled linseed oil. The dry powders are mixed together intimately on a hotplate, passed through a fine sieve, and made into a paste with the oil. Some people prefer a mixture of 2 parts of raw linseed oil to 1 part of boiled oil. Raw oil tends to retard and boiled oil to hasten hardening. The mixture should only be made as wanted, and should be worked up to a stiff but thoroughly plastic mass. It will take a good polish when dry.

Retarded Hemi-Hydrate Plaster.—Several proprietary plasters are of this type. They are much harder and more durable than lime plasters and also set quickly, thus saving the delay which is inevitable with lime plasters.

The retarded hemi-hydrate plasters are manufactured from gypsum. Gypsum when heated to about 300° F. produces plaster of Paris, which is too quick-setting for use as a wall plaster. By special treatment the setting quality is retarded.

The proprietary plasters of this type are of consistent quality and contain no chemical impurities, so that there is no risk of damage to decorations. Plaster boards are also made of this material, and some types can be used as a lathing board on which a skimming coat of a similar plaster can be applied after the joints have been covered with scrim.

Each manufacturer produces several grades of plaster for various purposes, and the instructions should be carefully followed both in selecting the grade and mixing.

OPERATIONS

Plastering may consist of one-, two-, or three-coat work. Single coats are rarely used in interiors, except for the parging of the inside lining of flues and airshafts, or the dinging of cellars, vaults, stables, garages, warehouses, and so on, which will be described at a later stage, as also two-coat work.

Three-coat Work.—This is usual with all good-class interior work. It comprises a *rendering* or *pricking-up* coat of coarse stuff, laid on $\frac{1}{2}$ inch thick, followed by a *floating* coat of fine stuff, $\frac{1}{4}$ inch to $\frac{5}{8}$ inch thick, and a *setting* or *finishing* coat of fine or setting stuff $\frac{1}{4}$–$\frac{1}{8}$ inch. Gauged stuff may be used for the floating coat. Special finish is occasionally used for ceilings, cornices, panels, etc., and for this fine stucco or patent cements are commonly used. We will describe this three-coat method as applied to walls and ceilings, as it covers all the necessary processes in plastering.

Preparation.—The preparation of bases or surfaces has already been dealt with, but in two- and three-coat work a further preparation is needed to ensure the plaster being finished with a level face and to the thickness specified. This is done by running screeds, or plaster bands, between fixed dots, serving the purpose of thickness gauges, on the rendering or pricking-up coat.

Rendering and Floating Walls.—The rendering or *pricking-up* coat, also called *scratch coat,* of coarse stuff is laid on with the trowel, the plaster being carried on a hawk. Some force must be used in applying this pricking-up coat, as part of the plaster must be squeezed between the laths so as to bulge out behind, more or less covering the back, thus forming a key to hold the sides of plaster and so adding to the support obtained by adhesion to the base. This coat must be levelled reasonably, but can be left with the rough ridges caused by the edge of the trowel. As a rule, however, an extra key is obtained by going over with a wire scratcher, making zigzag or circular indented lines. This must be done when the plaster is partly set but still soft. The surface is then ready for the next process, which is of great importance. Before dealing with this, however, it will be well to say a few words about applying this first coat on metal lathing. It has already been pointed out that the aim in applying plaster to metal lathing should be to ensure that sufficient of the stuff should squeeze through the mesh to form at once a substantial key and to afford some protection to the metal by fairly enclosing it in a casing of plaster. Too often the method to secure this end is to use undue force in trowelling, or laying on with extra force with a float. But this, besides entailing unnecessary expenditure of labour and time, tends to defeat one of the ends in view, because by using too much force the extruded portion of the plaster may be more or less "cut" by the mesh, thus, if not causing it to fall away altogether, certainly forming a weak joint and insecure key. Extra force must, of course, be used, but only reasonably exercised. The main point is to give attention to the consistency of the plaster. If it is of the proper consistency, a reasonable pressure will suffice to ensure extrusion amounting to something approaching back plastering. A slightly wetter mix will be required with wire-wove mesh base. With hollow rib expanded metal sheets sufficient pressure must be exerted to ensure the filling of the hollows, otherwise air-cushions may be formed, which would prevent proper

adhesion, and therefore rendering it probable that blistering and cracking would ensue.

Floating Dots and Running Screeds.—Dots are either nails driven into the coarse stuff or dabs of plaster into which short lengths of laths are pressed and placed about 1 inch below the cornice, 1 inch above the skirting or base of the wall, at equal distances from the angles and at such distances therefrom, in exact lines, as will divide the wall space up into convenient bays. These dots are fixed by means of plumb rule and bob and a gauge giving the thickness of the upper coats. The dots are connected together by twine so as to produce vertical or horizontal lines, generally the latter for interior walls, and serving as guides for running screeds, or bands, of fine stuff about 6 inches wide and to the level required. When the screeds are formed the nails or flat pieces of lath are removed and the void places filled up with fine stuff. The screeds must be allowed to set well, as they have to support the long rules by which the surplus plaster in the next operation is swept off and a level surface obtained.

Floating.—The second coat is applied with the trowel, usually to a depth of $\frac{1}{4}$ inch, bay by bay between the screeds, smoothed with a float, and any excess removed by passing a rule over the surface, the ends resting on the screeds. While the filling of vertical bays is commenced from the top, working downwards, with horizontal bays the work is begun from the base. When the bays are floated off and still only partially set, the surface is scored over with a comb or wire scratcher, as was done on the pricking-up coat; but for this floated coat a better implement for the operation is a devil float, which is a small square wooden float, with four lath nails projecting from the front about $\frac{1}{8}$ inch. The devilling is done by giving the float a circular motion all over the floated plaster, thus providing a key for the third coat.

Finishing Coat.—The finishing or setting coat is then applied with the trowel and finished with a float. If the wall is to be painted, stucco, or some other special plaster, is used for the setting; if to be whitewashed or coloured, with gauged stuff; if to be papered, with fine stuff. There may be variations here according to the class of building and the character of the finish desired. In some cases even a rough surface is aimed at.

Plastering for Painted Walls.—It has already been stated that carefully prepared stucco is the finish generally adopted when elaborate painting of the surface is intended. It gives excellent results. The following information, however, should be noted, from requirements carried out by the Building Research Station, to determine a fitting surface for artistic painting. It was found that plaster on a soundly constructed cavity wall in brickwork was free from danger of dampness, but that a solid brick wall always presents some risk in a country such as ours. In such a case it is better to apply the plaster to well-protected lathing insulated from the face of the wall in such a way as to cut off capillary

contact with the brick. From the tests made it was found that fat plastering lime run to putty and stored for not less than one month gave the best results if gauged with a hemihydrate plaster, the two more or less in equal volumes. To this should be added 2 parts of clean sand graded from coarse to fine. This for the ground coat, the finishing coat being a mixture of the lime and plaster either alone or with some plaster of Paris, but without sand. The materials and workmanship must be of the best, and for painting with oil colours or wax mixtures the plaster must be allowed time to dry. With water paints moist plaster is desirable.

Plastering for Panel Heating.—Panel heating is in many cases replacing heating by means of radiators, and this entails a great deal of responsibility on plasterers. Naturally the alternating heating and cooling of the elements behind the plaster causes it to expand and contract, with the result that cracking, from severe fissures to surface hair cracks, will occur unless the material is carefully selected, mixed, and applied. Commonly the firms specialising in panel-heating equipment supply a specification for plastering, and this should be scrupulously followed. As a rule the under coat is of hydrated lime with gauged gypsum plaster. The finishing coat is also of lime and gauged gypsum, and in this coat is trowelled paperhanger's canvas, but without a skimming coat. This is designed to minimise the tendency to cracking of the surface.

Pilasters and Columns.—On large-scale, highly decorative work, pilasters and columns are generally encased in fibrous plaster. In such cases the ordinary course is to procure casings from specialist manufacturers of fibrous plaster. These sections, if plain or of normal classic type, can often be provided from stock, though more commonly they are made from individual moulds prepared from designs supplied by the architect. When sections are obtained in this way the plasterer's task is greatly simplified, being reduced to the preparation of ground, the fixing of the sections, and the finishing of the work to hide ties and joins. As in most of these jobs fibrous plaster is required for casing iron or steel stanchions, difficulty is sometimes met with in fixing the material in position, particularly with detached columns of 10 feet or over in height, for then top and bottom fixing would not be sufficient for permanent work. Probably the easiest, and at the same time the most satisfactory, method to adopt is to make a tight-fitting cage, or casing, in two half-sections longitudinally, in fine galvanised wire netting, reinforcing wire mesh, or selected laths. The fibrous plaster sections are fixed (by means of wires embedded in the plaster and projecting at the back sufficiently) to the cage while still on the bench. With very large columns the fibrous plaster had better be moulded in three or four semicircular sections, and this is almost always done with the more complicated polygon shapes. But as a rule the cage, or inner casing, need not be in more than two longitudinal sections, though there is no reason why more should not be adopted should this add to convenience in handling. When the fibrous plaster has been securely wired to the inner casing it is fairly easy to fix the

casing, with its outer shell of plaster, to the iron stanchions, also by means of galvanised wire, taking care to wire firmly at top and bottom. It is then only necessary to fix in place the plaster moulded base of the column, and then the capitals, by which means the principal fixing arrangements are neatly covered up. Finally, when all has been perfectly adjusted, the plasterer has merely to fill up joints, or any other small imperfections, with the appropriate lime putty or mastic, smoothing down with a polished wood spatula having a curved end, and at the same time making good all defects, so as to obtain a perfect match in the design. It is necessary to emphasise that only clean, thoroughly galvanised wire should be used, that wire netting or reinforcing mesh must be well galvanised, and the iron or steel columns clean and protected with a wash of anti-rust composition, such as bituminous paint, otherwise the plaster will sooner or later be disfigured by rust stains, which will make their way through any decorative painting, gilding, or silvering.

Fibrous plaster, however, is not always adopted for this purpose of casing pilasters and columns, and then the plasterer's work becomes far more difficult, and will call for special tools as well as rules and templates adapted to the particular design of column.

Brick and stone columns should have their joints raked out and their surface hacked to afford a safe key for the plaster. They must be brushed down and well wetted before applying the plaster, in the usual way. Metal columns must be encased in a cage of wire netting or wire-mesh reinforcement, and this, or a skeleton cage of laths, is affixed when a square pier is to be converted into a circular column. If the core is of brick, stone, or concrete, cement and sand is used for the rendering or first coat; if the core is of wood, or cased in wood laths or metal lathing (including wire mesh), about one-quarter, by bulk, of coarse stuff should be added to the cement and sand. One part of cement to 3 of sand makes a good mixture for the floating coat. A devil float should be passed over rendering and floating to provide the required key for the finishing.

Before plaster is applied, however, it is necessary to fix plaster dots along the column to give the gauge for the depth of the coating. These dots are fixed on four sides of the column and reasonably spaced from top to bottom. In order to work the rule collars are fixed, replacing the screeds as run on flat work. These collars are of plaster, and give the exact circumference of the floated column. The collars are fixed on top and base, and in very tall columns at intermediate distances; this being particularly needed where the column is designed with an entasis, or swelling, which is usually placed slightly below the middle. Collars may be either moulded in the workshop or, which is often the easier method, squeezed on *in situ*. If moulded they are made in two half sections. Nails are driven into the four sides of the column to hold the collars in position, being held there by a small quantity of gauged putty and plaster, applied above and below. For pressed or squeezed-on collars

templates are used. These are cut out of $\frac{3}{4}$-inch sound board, the semicircular cut being smoothed and, of course, to exact gauge for depth of render and float, all templates being in duplicate. A band of putty and plaster is applied round the column to slightly more than cover the gauge dots. Then the semicircular cuts of the templates are smeared with linseed oil and pressed against the putty and plaster so as to secure a perfectly even circular band to exact gauge. The templates are suitably held in position and removed as soon as the collars have set. Unless the columns are of equal diameter from top to bottom, which is rare, because most columns, even those with an entasis, diminish towards the top, the collars will be of different dimensions, and so two or more moulds or templates will be needed. Any nails used for supporting either dots or collars should be removed when floating.

If the dots and collars have been properly fixed there should be no great difficulty in plastering plain columns. It should be three-coat work: render, float, and setting, observing the rules mentioned above as to mixtures appropriate for different kinds of cases. Each under coat should be gone over with a devil float. When applying the finishing coat (in the majority of cases Keene's or other "patent" plasters are used for this purpose on interior, and often also for outside work), the stuff is laid on partway round the column from top to bottom, filling out to the full face of the rule, the float being worked round the circle, all being made smooth and firm. As a rule the under coat is scoured with a cross-grained float and the finishing stuff laid on with the trowel and finished off according to the nature of the setting. There is no difference as regards the laying on whether the column is of equal circumference from top to bottom or if it should taper, that is, belong to the diminishing order, though, as already mentioned, in the latter case the collars would vary in dimensions.

When, however, the columns are fluted, specially prepared rules with templates cut to the design of the flutings will be necessary. These vary according to the design, the shapes and dimensions being obtained from the working drawings supplied by the architect. The templates may be of wood, carefully smoothed; but if a number of columns have to be run, tinned plate is far more satisfactory, particularly where sharp arrises are required. The rules with their templates must be used both on the floating and finishing coats.

On all (but the very shortest) columns two men are needed to work the rule, as these are too long to be handled from the middle, while firmness is required. The men must work in perfect unison or the work will be unsatisfactory, with added waste of time and material.

After the shafts of the column have been run and the plaster has set, the bases and capitals are fixed, being tied with galvanised wires and secured by means of putty gauged with plaster, or secured in position with putty and plaster only. As a rule the bases and capitals are moulded in the workshop, usually plaster moulds, lacquered or waxed inside, are used,

or, when the design is intricate with undercutting, gelatine moulds are adopted. If the bases and capitals are very plain they are roughed out, rendered, floated, and finished, templates being applied, as in the case with the shafts. At other times, especially with Gothic and fancy designs, the capitals are roughed out, a coating of fine stuff applied, and then the modelling is done *in situ*, just in the same way as with decorative ceilings, etc. For this kind of work artistic ability and skill in the use of modelling tools are required; it also takes up more time, so is decidedly costly as compared to shop work.

If columns are to be decorated with projecting circular rings or square collars, the rings and collars are generally moulded in the workshop in two sections. These may be fixed to the core before plastering the shaft, which certainly makes a safe job. But many prefer to run the shaft from top to bottom, at all events for render and float coats, as this makes a quicker, easier, and cleaner job than when carried out in sections. Should this be done it will be necessary to cut back the plaster to the core, fix the two halves of the rings or square collars, and then complete finishing. Roughing out these rings and collars on the shaft and finishing by the help of templates is possible but not advisable, unless the projection is very slight, and the thickness not great. Under the latter conditions, however, this method certainly tends to better uniformity in outline and material.

Pilasters practically form two distinct classes: (1) engaged columns, and (2) flat engaged pillars, or sections of piers, both designed on the same standard measurements as the relevant column. That is to say, both are built into, or are attached and project from, a wall, or in some instances form the sides of a massive pier. An engaged column may project a full half-circle, less than the semicircle or more, almost, indeed, to the full circle. Thus we may have the clustered column, more particularly associated with Gothic architecture, where a number of columns of equal dimensions are grouped together to form a solid pier, or where a number of small columns are clustered round and attached to a larger central one. The flat pilaster is treated much in the same way as the engaged column, it too having more or less projection according to design. While this is not the place to discuss the design of columns or pilasters with the standard measurements for parts in the different Orders of Architecture, it is well to state here that there are rules, founded on the requirements of good design and construction, as to the relative amount of projection. If pilasters are placed behind columns and fairly close to them, they should not project more than one-eighth of their diameter. When, however, they are placed 6 feet or more behind the column, then the projection should be at least one-sixth of their diameter. But when pilasters are used alone, as structural or decorative parts of a design, the projection should be not less than one-fourth of their diameter, and may, in the case of engaged columns, be more, in order to give regularity to the returned parts of the capital. As to the actual process of plastering

the pilasters, the same methods are used as for the column, though, of course, special templates will have to be cut.

Panelled Coves, of segmental or elliptical form, with panels formed by mouldings springing from the wall or cornice, and finishing at an intersection with a beam, other moulding, or central rosette, require careful treatment. Horizontal screeds are run in the usual way, but the vertical screeds should be pressed, or squeezed, accurate templates being used for the purpose. With coves of large dimensions three men will be needed for this work, two to hold the template and the third to form the screed. Dots are applied in the usual way, great care being taken that they are perfectly level, and for this purpose the levelling rule should be provided with a fillet on which a spirit level can rest. The mouldings are then run, being roughed out with the plaster and shaped by means of templates. The panels are then filled in with the trowel and gone over with a small float. Some plasterers prefer to mould the mouldings, especially when of complicated design and possibly diminishing as they rise, in the workshop. If very long they should be cast in sections and have canvas or scrim embedded at the back. When this method is adopted the cove is usually finished, or at least floated, and the plaster cut back to the core or base to plant the mouldings, after which the finishing coat is made good, including the filling in of joints.

Panelled Beams with mouldings on their sides and on the soffit will require screeds on each side and one along the middle of the soffit. Usually the mouldings on the sides are run from rules fixed on the side of the beam with a rib bearing on the soffit. When the stile and mouldings on the soffit are small, the mould should be made to run the face, stile, and soffit moulding in one operation. But if the stiles are broad, the moulding on the sunk part in the centre of the soffit should be run from a parallel running rule fixed in the centre of the soffit. Elaborate mouldings may be run separately and planted.

Ceilings.—Three-coat work on ceilings differs little from render, float, and set on walls, except that greater care is required, especially in finishing off. The surface is marked off in the pricking-up coat as is the case with walls. Scratching may be carried out in the ways already indicated, although the scratching instrument more commonly used is made up of three or four short lengths of laths, pointed and chamfered at one end, nailed together at the other, and spread out fanwise, and bound in this position by a band of leather or tinned iron sheet just below the pointed ends. The scratching is done criss-cross fashion, in diagonal lines in each bay. The surface is then floated. When the floating is set, it is scratched ready for the final coat. This is usually skimmed on with a skimming float, the setting coat commonly being laid on in two coats. After skimming on the setting, the coat is finished by trowelling, passing the trowel backwards and forwards, and using a wet brush on the plaster to facilitate the smooth working.

Ornaments on ceilings, such as mouldings, are blocked out with coarse stuff, covered with setting, mastic, or other special plaster, and shaped as required by means of moulds or templates.

Cornices.—When cornices do not project more than 2 inches they are blocked or roughed out with coarse stuff, carried down to the rendering or pricking-up coat, floated with setting or mastic, and run out with a template, which shapes the mouldings and sweeps off surplus stuff. When cornices are of greater projection, or if very deep, a cradling conforming to the rough outline of the cornice is formed by wooden brackets and laths. As a rule brackets are cut from $\frac{3}{4}$-inch to $1\frac{1}{2}$-inch boards, the profile showing the shape of the cornice. These are placed in the angles of the room, also at convenient spaces along the walls, being tailed into the walls or otherwise firmly fixed. Then the brackets are connected by means of laths, which are rendered, floated, and finally receive the setting, when the template is run over them.

Enrichments, such as medallions, pateræ, ornamental brackets, etc., are usually moulded and left with roughened bases. If very large, they are moulded hollow with a core of tow or similar material. These are planted in prepared plaster beds, and when pressed down in position, a smooth connection with cornice, ceiling, and wall is made with fine stuff or mastic. Occasionally modelling is done *in situ*, when the enrichment is roughed out with coarse stuff, floated, and coated with fine stucco or mastic ready for the modeller.

Pattern Staining.—Plaster work, more particularly on ceilings, is very liable to be disfigured by dark stains, more or less representing the lath or other composite backing. This may occasionally be traced to bad work or inferior materials. For instance, unseasoned sappy laths may stain thin coats of plaster. Then again, when a two-coat ceiling is close up to an imperfectly boarded floor, with wide crevices between the boards, staining may occur. The phenomena more generally are due to what is termed "thermal precipitation." That is to say, particles in the air are set in motion by the rise in temperature; when the temperature is even the motion of the particles will be even and their precipitation against a wall or ceiling will be so equal that no perceptible difference results, but if for any reason there are variations in temperature, the direction of the particles will be diverted towards the cooler zones, and thus the particles will be unequally deposited, causing differences of coloration in wall or ceiling. This matter has been investigated by the Building Research Station, and the results obtained are summarised here. Laths being poorer conductors of heat than plaster, it follows that heat will flow more freely through the gaps between the laths; consequently, if the air in a room is dust or smoke laden pattern staining occurs automatically and fairly rapidly. It was found that calcium sulphate (gypsum) plasters stained more rapidly and distinctly than lime plasters. Pattern staining is retarded, decreased in intensity, and finally overcome by increasing the thickness of the plaster, which tends to equalise thermal

conductivity. This increase of thickness of plaster has its limits, and so under certain conditions of dirty atmospheres and considerable variations of temperature, other remedies must be sought for, the most promising of these being lagging the upper surface of the plaster. This is, of course, largely attained with back plastering, though this is not always sufficient. Experiments showed that a backing of slagwool 1 inch thick markedly retarded and reduced staining in a smoke-laden atmosphere. A composite layer of cotton-wool, covered with slagwool, each $\frac{1}{2}$ inch thick, not only overcame pattern staining, but reduced the total deposit of smoke. Slabs of compressed straw proved fairly efficacious.

Condensation.—In damp situations, subject to mists and fogs, a hard-setting, dense plaster with high polished finish is undesirable, as the hard, polished surface greatly favours condensation, often causing walls to drip with moisture, which may be mistaken for dampness penetrating through the walls. In such cases a more porous plaster is indicated, with a rough surface and unpolished finish. Such plastered surfaces should not be painted with oil colours, but distempers may be used.

Acoustics.—Churches, public halls, theatres, music rooms, and the like require very careful attention from the plasterer. Hard, dense, highly polished plasters are as bad in this connection as they are from the point of view of condensation, as they cause unpleasant reverberations and interfere with clear hearing. Porous plaster with rough, unpolished finish is indicated for use under such conditions. Special acoustic plasters are on the market, which, when gauged, generate gases. These gases cause the plaster mass to be permeated with small air bubbles, honeycombing it, and rendering it absorbent. Such plasters must be applied quickly after tempering with not too much trowelling, and on polishing. They may be stained, but should not be painted with oil colours or enamels.

Two-coat Work.—Two-coat work, or float and set, is usually adopted for application to brick and concrete walls; also on ceilings when applied to concrete or other solid soffits of floors. Also for breeze block. pumice-stone block, tile, or similar partitions.

Render and Finish is one-coat work and is adopted for cheap cottage work, the walls of lobbies, W.C.s, sculleries, factories, etc. It is usually carried out with a mortar of 2 parts of Portland cement to 3 parts of sand. Working is improved if a little lime putty is added, or hydrated lime. The walls are thoroughly damped, a thin layer applied with the trowel, angles wiped out with a feather edge, and finished with a skimming float.

Dinging is the cheapest form of one-coat work, and in some regions is often performed by bricklayers or even labourers. It is applied to cellars, vaults, warehouses, and more rarely to cottage walls. A poor type of coarse stuff is used, without hair, and is applied in a thinnish layer on the dampened wall with a trowel. Before it has thoroughly set it is gone over with a stock brush, a grass brush, a piece of coarse sacking,

or even a broom, to smooth out and leave with a rough surface. Dinging is almost always limewashed.

Parging.—Parging is applied to chimney flues to form the inner lining, airshafts, and the like, or to very old brick walls. It is a rich plaster mortar with an addition of cow dung. In flue and shaft work the parging is done as the work of construction progresses.

Defects.—Hair and map cracks, small, shallow, and irregular, will occur owing to too dry or wet a mix or inequality in the drying or expansion and contraction of the base. Allow to dry thoroughly, and go over the surface with a thin wash of lime putty or any other special cement that had been used as a finish. Isolated and deep cracks are more serious. Time must be given for thorough setting and settling. If the cracks then increase, it will be necessary to examine the lathing, and possibly pull down the work. If the cracks do not increase in length and depth, cut out the defective part, ½ inch on both sides of the crack, with an undercut section. If the base is of wood laths, brush off adhering plaster, damp thoroughly; if metal, clean well. Then apply coarse stuff as a base and level up with setting stuff. It is advisable to wet the edges of the old plaster thoroughly in order to prevent undue suction which would prevent the new plaster adhering securely. After the patch has set, it may be necessary to go over it with a thinned setting or a wash of lime putty. Keene's cement is often useful for filling up cracks, particularly in mouldings and cornices.

Quantities.—Quantities will vary more or less according to the character and condition of the base to be plastered. The following are approximate averages for covering 100 square yards: one-coat work—lime 1 cubic yard, sand 1½ to 2 cubic yards, hair 15-16 pounds; two-coat work—lime 20 bushels, sand 2 cubic yards, hair 16 pounds; for roughcasting ¾ cubic yard of gravel; three-coat work on brick or stone—lime 2½ cubic yards, sand 2½ cubic yards, hair 27-30 pounds; three-coat work on laths—laths 22 bundles, nails 14 pounds, lime 2½ cubic yards, sand 2½ cubic yards, hair 32 pounds. Cement: neat, laid ¾ inch thick, 25 bushels; gauged half and half sand and Portland cement, 13 bushels each; 1 to 2 mixture—Portland cement 9 bushels, sand 10 bushels; 1 to 3 mixture—Portland cement 6½ bushels (full measure), sand, 17½ bushels.

SPRAYING PLASTER

Plastering by spraying with compressed air is possible. Such machines, known as cement guns, are largely used in America, and have found favour on the Continent. In England they have been chiefly used in rendering outside and inside walls with neat cement or cement mortar, but are equally fitted for spraying plaster. The machines consist of an upper chamber or hopper, through which the material is fed, and a lower chamber fitted with valves, into which air under pressure is pumped. To

this lower chamber a hose pipe is attached with a fairly complicated spraying nozzle at the other end. By means of a hand wheel or other device the inlet to the nozzle is controlled. When fully open, and the lower chamber is under air pressure, a jet of cement mortar or plaster is shot out with considerable force, so that when of the proper consistency it adheres strongly. With practice a fair spread and an even layer of any reasonable thickness can be obtained. The thickness of any layer, however, should not be less than ½ inch or more than 2 inches: any increase should be secured by a second, and if necessary third, spraying. The most satisfactory results are obtained when the nozzle is held at from 30 inches to 35 inches away from the base, and at an angle of 90° from the face; but cement mortar can be shot from a greater distance, and, indeed, one of the claims made in favour of spraying is that it largely minimises the use of scaffolding. A 25 h.p. (or 18 kW.) machine is capable of spreading 950 square feet 1 inch thick; a 35 h.p. (25 kW.) machine 1,500 square feet, ; a 45 h.p. (35 kW.), machine, 2,000 square feet. Three men are required for operating the smaller and medium machines and four for the largest. They appear to be economical on large jobs, such as housing schemes.

FIBROUS PLASTER

Although fibrous plaster can be made in any workshop, it is almost invariably obtained from manufacturers who employ experts. It is obtained either in special sections from individual designs or in sheets from stock patterns. There are many variations in actual production and the materials used. Essentially the processes are these: a model is made of a design in high, medium, or low relief, and moulds are taken from these, gelatine moulds in the first two cases, plaster moulds for low relief. A layer of suitably prepared plaster is poured into the mould, means being necessary to rock the moulds of large section and deep relief in order to secure complete and even spread of the plaster. Then scrim or canvas is pressed in, and a further layer of plaster applied. These processes may have to be repeated with elaborate designs. The scrim or canvas may or may not be subjected to special treatment before use. When necessary the plaster casting with its reinforcement of scrim may be further strengthened with two dipped in plaster or with lathes, the aim being to keep the section as light as possible. Elaborate mouldings and enrichments of all kinds are thus obtained and weight kept down. Fibrous plaster is made in slabs, sheets, sections of cornices, capitals, and so on.

Fixing of fibrous plaster is possible on wood, soft brick, or porous concrete. Nails may be used for temporary work, but permanent work should be done with screws, counter-sunk, the heads varnished with shellac. and the holes stopped with fine plaster. The edges of all sections should be cut at a slant, each side, or end, in an opposite direction, so that when two such sections are brought together they fit closely, the slight visible

line of junction being filled in and smoothed over with fine plaster. This gives a far better finish than a butt joint, and one less likely to spring.

Although fibrous plaster is fairly tough, it needs careful handling, edges and high-relief enrichments being the vulnerable parts. Holes for screws should not be sunk too near edges and only on plain surfaces. Large sheets will require support in other parts besides the edges, and while the sheets are comparatively light in weight, it must be remembered that they have not the advantage of support from back adhesion as in the case of ordinary plaster work. For this reason special framing may be necessary to make a secure job with a large, elaborately decorated ceiling. Cradling, fixing fillets or blocks, may be required in the case of deep, projecting cornices, friezes, over doors, and the like. This, however, is very simple carpentry work, only calling for sound material and strong framing up.

Most fibrous plaster does not require decoration, but it can be limewashed or painted and gilded. It can also be dressed at the back with a waterproofing and fireproofing solution.

FLOORS

Concrete and Cement.—Concrete floors are usually the work of the concreters, but the cement finish is often left to the plasterers. Concrete for floors varies according to position. For solid floors laid on the ground the mix may be composed of Portland cement 1 part, sand 1 part, aggregate (broken brick, broken stone, or ballast) 4 parts; for upper floors on pre-cast beams, terra-cotta tubes, or metal lathing a 1 : 2 : 4 mix is common, the sand graded, the aggregate coke breeze, clinker, broken brick, or limestone. On ground floors the concrete bed should be from 3 inches to 6 inches thick according to the nature of the ground, being laid on well-drained soil with a consolidated foundation of hard core 6–8 inches deep. Upper floors on girders will require centering, as the girders should be embedded in the concrete, with a layer about $\frac{1}{2}$ inch below the soffits and $\frac{3}{4}$ inch above the tops. On metal laths a rather fine aggregate should be used, so that part of the mix should extrude; the layer should be $1\frac{1}{2}$ inches and the under part of the lathing back plaster or rendered with cement mortar. Floors are laid in bays of convenient width between screeds, which are removed soon after the initial set and the joints filled up later with the same stuff. If the surface is to be cement floated, the floor is again laid out in bays with screeds and filled in with a mix of Portland cement 1 part, graded, sharp sand 5 parts, to a depth of $1\frac{1}{2}$ inches. If it is to be a cement-mortar floor on metal lathing the depth should be 3 inches, with a top dressing of Portland cement 1 part, fine sand 2 parts, $1\frac{1}{2}$ inches thick, if to be left bare. Such floors should not be over-trowelled, as that makes them too slippery; finish lightly with the flat of the trowel. Carborundum powder may be spread on steps or in corridors, more particularly when they have a slope, as this makes the surface less slippery and harder wearing. If the floors are to be

boarded over, both concrete and cement mortar surfaces as soon as dry should receive a coat of hot tar, as a precaution against dampness and dry rot. But it is useless attempting to tar or pitch a damp surplus. The removal of screeds presents some difficulty. The best way is to rest boards on bricks, so that the men can kneel on these while removing the screeds, filling up and levelling.

Terrazzo.—A terrazzo or crazy mosaic floor is laid on a foundation of rich concrete with a top dressing of Portland cement 1 part, marble dust or silver sand 2 parts, laid $1\frac{1}{2}$ inches thick. This is to receive the irregular-shaped fragments of marble or granite, which should not be more than $\frac{3}{4}$ inch in any direction and not more than $\frac{5}{8}$ inch deep. They must, of course, be flat, and have one side smooth and polished. The paving fragments are bedded in grout at random, but close together. If two or more colours are used, they should be mixed together, so as to produce a variegated effect. After bedding the surface is flooded with a liquid grout of cement and fine silver sand, well brushed in, the surplus squeezed or sponged off, and when the surface is nearly dry it is washed. A rougher form is made by throwing on the cement mortar bed chips of coloured marble or granite and smoothing in with a small wooden float. Usually a white cement is used, but colours, or coloured sands, are often used to give contrasting effects, as the matrix is always conspicuous. Forge ashes, ground slag, brick dust, red oxide of lead, carbonate of copper mixed with marble dust and lime, green enamel, are useful colouring materials for this purpose.

An interesting policy has been adopted by the Cement Marketing Company in producing in addition to white also cream, buff, and red cements for use with selected aggregates, chiefly for flooring. After laying and smoothing with trowel or float the surface is polished either by means of a power polishing machine or carborundum bricks. Floors thus treated do not dust. The Cement Marketing Company also send out mixtures (cement and aggregates) in paper bags, only requiring gauging with water. The mixtures are made up according to the effects desired.

Plastic Floorings.—There are numerous kinds of plastic floorings, most of them proprietary mixtures. These require careful laying on perfectly level (but rough surfaced) foundations, thoroughly dry and free from dust. The advantages of such flooring materials is that they are usually fairly elastic, and therefore not apt to crack when well laid, can be shaped to awkward ground plans, and carried up the walls to replace skirtings and provide rounded angles. A form of plastic flooring much used, because it can be laid on a concrete or a boarded foundation, is fairly cheap, and easily handled, is a composition of magnesia cement and sawdust. It thus uses up waste material from the carpenter's shop. But it must be understood that only fine sawdust is permissible; all shavings and chips should be removed. Good mixtures are made with from $2\frac{1}{4}$ to $2\frac{3}{4}$ parts by volume of chloride of magnesia to 1 part of fine,

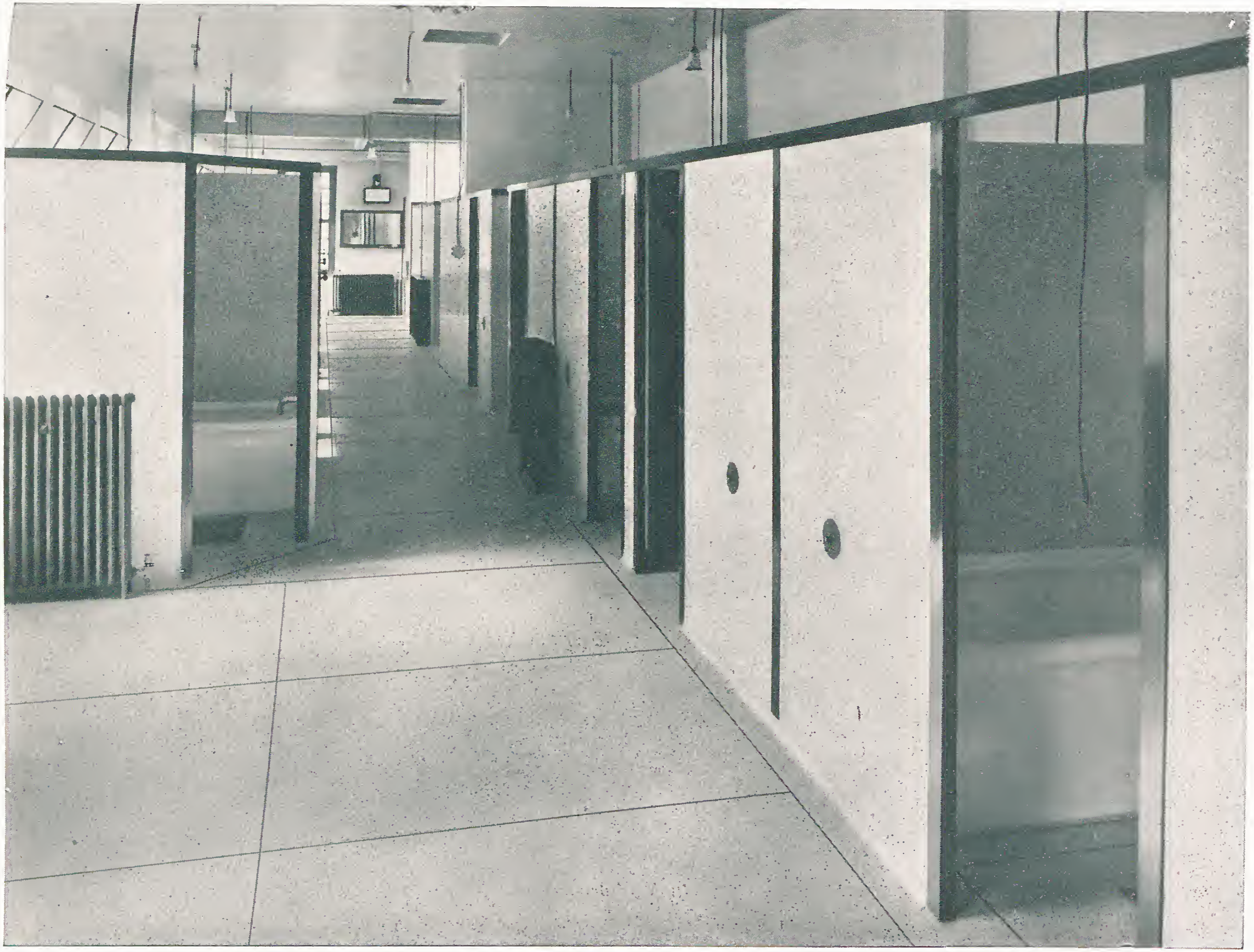


FIG. 181.—A MODERN PUBLIC BATHS. PARTITIONS AND FLOORS IN TERRAZZO.

clean sawdust. It should be a stiff paste, just plastic enough to be laid with a trowel and smoothed with a wooden float. It is laid from 2 inches to 4 inches thick. Such a flooring will be dry in about 18 hours in warm weather if not more than 2 inches thick or 48 hours in cold damp weather if 4 inches thick, though it should not be walked upon for a week after laying. Floorings of over 2 inches thickness should be laid in two coats, the top one only being coloured with iron oxide, yellow ochre, or umber.

Quantities.—1 cubic yard of lime, 2 cubic yards of sand, 3 bushels of hair will cover 75 square yards of render and set on brick or concrete; 70 square yards on lath; two coats and set on brick or concrete 65 square yards; on lath, 60 square yards. 1 bushel of cement, or concrete and fine sand, will cover 1 square yard of $1\frac{1}{2}$ inches thick, or $1\frac{1}{2}$ square yards 1 inch thick. 1 cwt. of mastic and 1 gallon of oil will cover $2\frac{1}{2}$ square yards $\frac{1}{2}$ inch thick. 1 cubic foot of slaked lime will cover 100 square feet for first coat, 200 square feet for second coat.

A bag of plaster contains 14 pounds, 7 bags equalling 1 bushel. A sack of Portland cement weighs 200 pounds (2 centals), and equals 2 bushels. A sack of lime weighs 156 pounds and equals 3 bushels. 14 to 15 pounds of hair equal 1 bushel.

All the above quantities are approximate, as the nature of the base, more particularly with laths and expanded metal, has a marked influence. Where something approaching back plastering is aimed at, quantities must be increased by from 20 to 25 per cent.

Measuring and Pricing.—Most plaster work is measured by the square yard (per yard super) or by the foot run, according to its nature. The Standard Method of Measurement states that "the thickness of two-coat work, exclusive of keys (*i.e.* grooves or open joints in brickwork or spaces between laths) shall be regarded as not exceeding $\frac{5}{8}$ inch, that of three-coat work as not exceeding $\frac{7}{8}$ inch, and that of two-coat work in patent plasters as not exceeding $\frac{1}{2}$ inch. Any requisite dubbing and any additional thickness shall be specially stated in the item in question." However, as a rule three-coat work is taken as $\frac{3}{4}$ inch thick, and any additional thickness charged as dubbing.

Flat work, ordinary ceilings, and wall linings are measured and the length multiplied by the width in order to obtain the square or superficial dimensions. Separate measurements must be made for varying types of work: rendering, dinging, two-coat and three-coat work, and special finishes, such as with patent plasters.

Exterior and interior work must be measured separately and kept apart in the statement, and any special preparation of surfaces also set down as distinct items.

Ceilings are measured from wall to wall, or from the inner member of the cornice. Sloping and coved ceilings and plastered surfaces between exposed rafters should be measured separately. Soffits of staircases as ceilings.

Measure fair face to brickwork or stonework and internal painting

per yard super. On lath, add to the height of wall one-third of the height of the cornices above the moulding for stucco, two-thirds for laid and floated work.

Cornices in plaster exceeding 12 inches in girth (to include Scotch bracketing or other similar bracketing, and dubbing when required) by the foot run. Soffits, bands, margins, etc., under 12 inches girth, per foot run. Cornices 12 inches in girth and under end skirtings according to schedule; quirks, beads, arrises, throatings, per foot run. For cornices 12 inches girth or over, take out one of the projections of the cornice and multiply per foot run. Girth cornices, including space occupied by enrichments, mouldings, from the score of the enrichment or moulding to the wall, allowing 1 inch more for the screed. Enrichments, mitres, and stopped ends should be counted. Pateras covering mitres not to be counted, unless within frames or coffers.

Skirtings per foot run. Reveals and margins, if so specified, per foot run, otherwise per foot super. Where no wood ground is fixed and the skirting is nailed to plugs, the measurement of plastering is usually half the height of skirting.

Patching and repair work generally, by the square yard or foot run, plus 5–10 per cent.

Washing, stopping, limewashing, colouring, distempering per square yard, the number of coats to be stated. If colouring or distempering is on lining paper, one piece in seven is allowed for waste, so that with ordinary lining paper one piece is taken as 6 square yards.

Roughcasting and similar work per square yard super. Narrow soffits per foot run. Stucco bondings or string courses per foot run. Colour or cement washes over roughcast per yard super or foot run as the case may be.

All window, door, or other openings to be allowed for, their areas being deducted from the overall superficial measurement.

Patches and repair work generally may be charged time and material (with, of course, the usual trade profits allowed on these items), or by measurement plus 5–10 per cent. added for extensive work.

Ordinarily prices are arrived at after taking into consideration labour (including labour insurance), cost of materials (each of which should bear its quota of profit, usually a percentage on gross cost, plus discounts), and overhead charges. Overhead charges necessarily vary greatly according to circumstances, but should cover rent, rates, and taxes, lighting, salaries of non-labouring staff with general office expenses and depreciation on plant and tools.

It is generally assumed that in plastering the relative cost of labour and materials (including supply of scaffolding, etc.) is as three to four. It may also be taken for purposes of estimating and pricing that on ceiling work one plasterer with his labourer will lath, float, and set $1\frac{1}{2}$ square yards per hour. While on brickwork a plasterer and his labourer will render and set 3 square yards per hour.

CHAPTER 13

WALL AND CEILING COVERINGS

FLAT sheetings of several materials are now widely used for lining walls, partitions, and ceilings instead of plaster.

In comparing these materials with plaster, it should be remembered that plaster has the advantage of providing a continuous jointless lining with no spaces at the back, but it is liable to crack and will not withstand heavy vibration, and there is some delay while the coats dry out. Building boards can be quickly fixed by simple means and there is no danger of cracking. There are various kinds of building board offering a variety of decorative surfaces and physical characteristics, so that a type can be selected to suit the conditions—an impervious type for a damp position, an insulating type for sound or thermal insulation, a matt-surfaced type for distemper treatment, and so on.

Sheeting Materials.—The chief sheeting materials are :

- Asbestos-cement flat sheets and panels—
  - Natural surface ;
  - Polished and decorated surfaces.
- Fibre Boards—(Wall-boards)—
  - Loosely compressed ;
  - Highly compressed.
- Reconstructed wood—dense hard structure, stronger than natural softwoods, free of faults, works like wood.
- Plaster Boards—
  - Smooth surface as finished surface ;
  - Rough surface for finishing with skimming coat.
- Metal Sheets.
- Opaque coloured glass.
- Sound-insulating sheets of various materials ; e.g. cork, wood wool between sheets.

The impervious materials, asbestos-cement and metal sheets and panels, may be used for exterior cladding, as described in Chapter 15, Vol. II. In this chapter the uses of the foregoing materials for interior linings will be dealt with.

ASBESTOS-CEMENT

This material is impervious, fire-resisting, and vermin-proof, but is rather brittle and if fixed in positions where it must take knocks should be supported at rather close intervals.

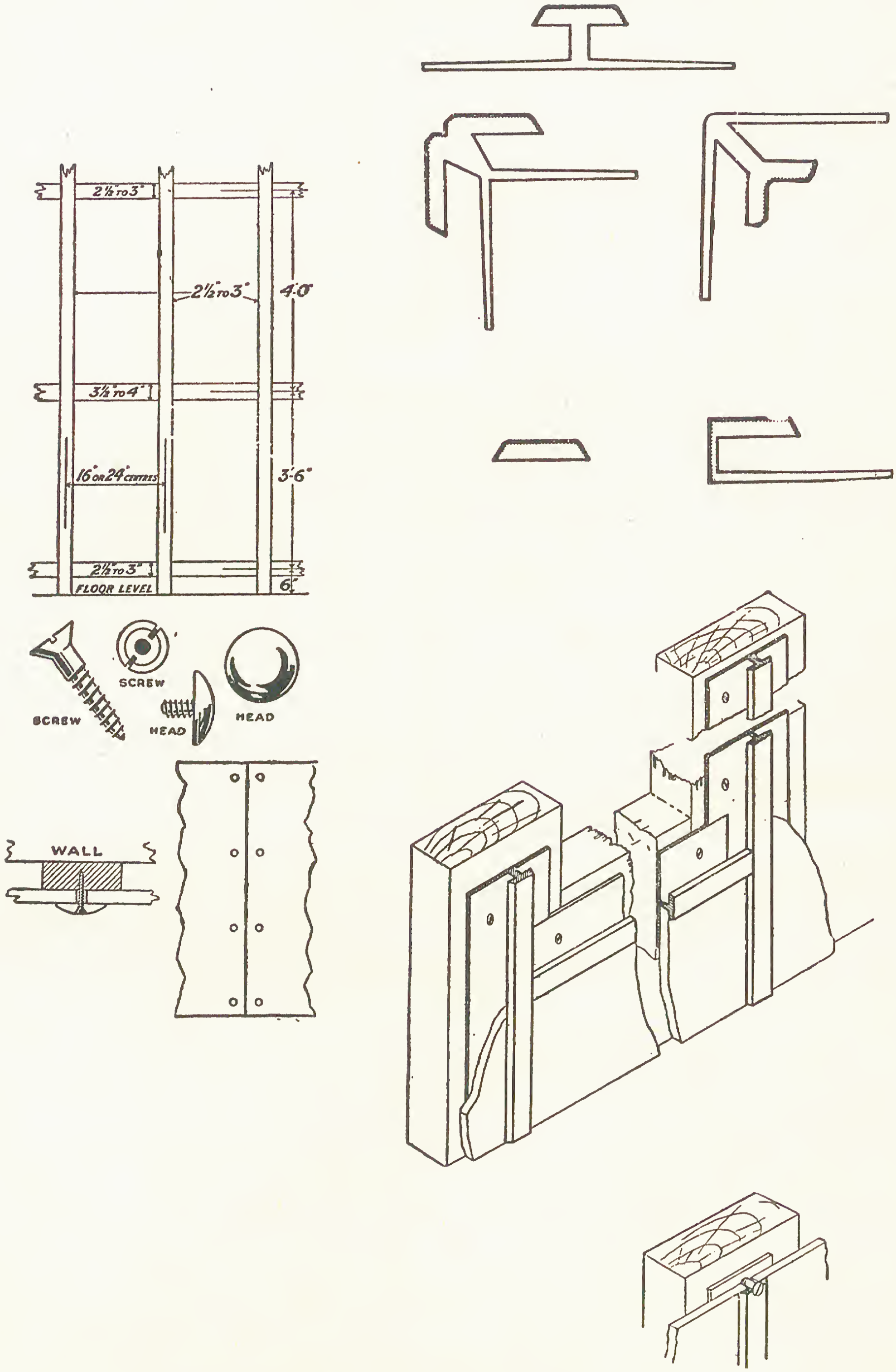


Fig. 182.—Fixing methods for decorated asbestos sheets. (*Left*) Fixing to wood battens (*Right*) Fixing with aluminium-alloy sections.

Ordinary asbestos-cement flat building sheets are made in sizes 6 × 3 feet, 6 × 4 feet, and 8 × 4 feet. They are suitable for lining walls in kitchens, bathrooms, etc., and can be distempered or painted, after treatment with a suitable primer. They can also be used for forming cupboards and pipe casings.

Embossed sheets are made which when painted have an appearance similar to the finish of plastic paints.

Plain white glazed sheets of asbestos-cement are excellent for lining

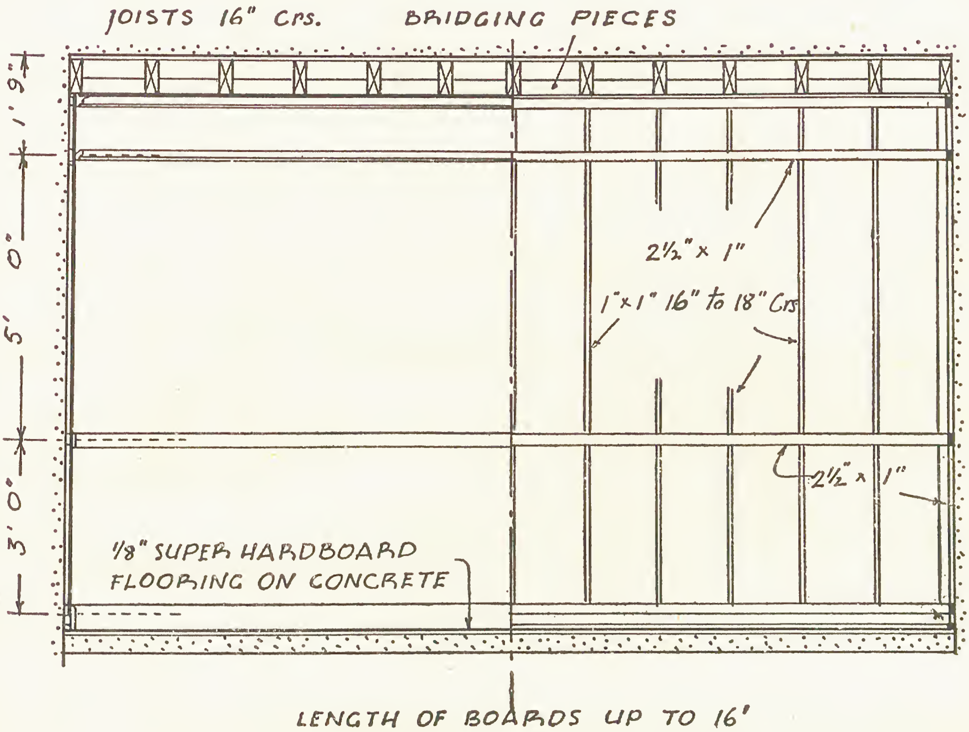


Fig. 183.—Typical layout for fixing wall-boards horizontally. Vertical joints occur at corners only.

kitchens, bathrooms, canteens, etc., where a glazed, easily cleaned surface is required.

Decorated sheets with a coloured glazed surface are made, and also stipple-glazed and marbled finishes. Glazed flexible sheets are used where curved surfaces are required.

Fixing Asbestos-Cement Sheets.—The sheets are fixed on wood battens which are plugged to the walls. It is advisable to use fibre or other proprietary plugs as the old-type wood plug is unreliable.

The sheets may be cut with a carpenter's hand saw or scribed on the glazed side and broken over a straight edge.

The sheets are fixed to the battens by drilling and counter-sinking holes for screws. They should be butt-jointed, but not pressed tightly

at the edges, and the join covered with wood or metal cover strips. Alternatively, they can be fixed without cover strips by using chromium-plated head screws.

Battens should be at least $2\frac{1}{2}$ inches $\times$ $\frac{5}{8}$ inch fixed at 16-inch to 24-inch centres and along all edges of sheets. Intermediate support should be provided by battens fixed half-way along the length of the sheets. Sheets should be screwed not too tightly, at 12-inch to 18-inch centres along all four edges.

Wood cover strips can be fixed with ordinary wood screws with countersunk heads, or oval nails may be used—the nail heads being sunk below the surface and the hole stopped with putty or plastic wood, so that the fixing is invisible, when the strips are painted.

Metal Fixing Strips.—These are obtainable in anodised aluminium alloy and chromium-plated brass. They have a very neat and clean appearance and are as simple to fix as wood cover strips.

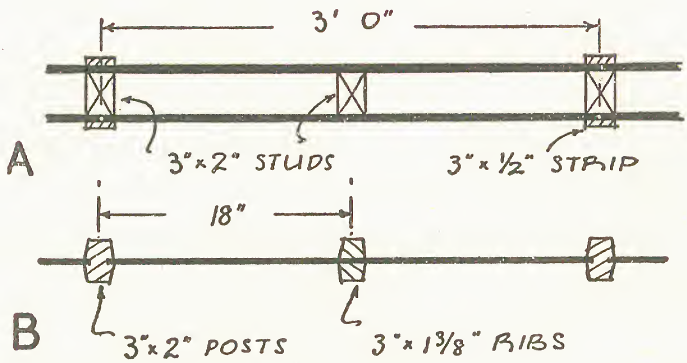


Fig. 184.—A. Double partition, timber-framed with wall-board both sides. B. Single partition, suitable for forming cubicles, using strong hardboard set in grooved posts and stiffened with ribs.

Several patterns are illustrated in Fig. 182, including a very convenient section for making butt joints in horizontal or vertical runs, angles, and a section for edging or capping. These strips are made in 6-foot and 8-foot lengths and are cut and drilled on the site. They are fixed by means of wood screws to battens or studding.

WALL-BOARDS

Most sheetings marketed under proprietary names as wall-boards or fibre boards consist of shredded wood fibres. There are also paper-pulp boards up to $\frac{1}{4}$ inch thick, but these bend too readily and are liable to be quickly affected by atmospheric moisture, so that they are not much used in permanent buildings.

The boards made of wood fibre may be divided into three types according to relative density:

Low-density fibre boards, $\frac{5}{16}$ inch thick and upwards, largely used

instead of plaster for covering walls, partitions, and ceilings, and also used for thermal and sound-insulating purposes.

Semi-hardboards, $\frac{1}{8}$ inch to $\frac{1}{2}$ inch thick. These are rather highly compressed in manufacture, and are much less absorbent and also stronger than low-density fibre boards. In quality and nature they are not unlike whitewood ply sheets.

Hardboards, $\frac{1}{8}$ inch to $\frac{3}{16}$ inch thick. These are very highly compressed and have strength and resistance to moisture greater than natural softwoods. They can be used in exterior work with ordinary oil-paint protection.

1. Insulating Boards.—The low density of these boards give them high thermal and sound insulation properties. The density is not more than 25 lb. per cubic foot, and the minimum nominal thickness is $\frac{1}{2}$ inch.

Insulating boards may be of homogeneous structure, or laminated with layers cemented together. Another type is impregnated with bitumen to make it suitable for use in damp situations.

An acoustical board is made which is of lower density than normal insulating board, and in some makes the boards are mechanically perforated to increase sound absorption. Acoustical board is used for correcting sound reverberation in concert and lecture halls, offices, and other rooms where special acoustic problems have to be dealt with.

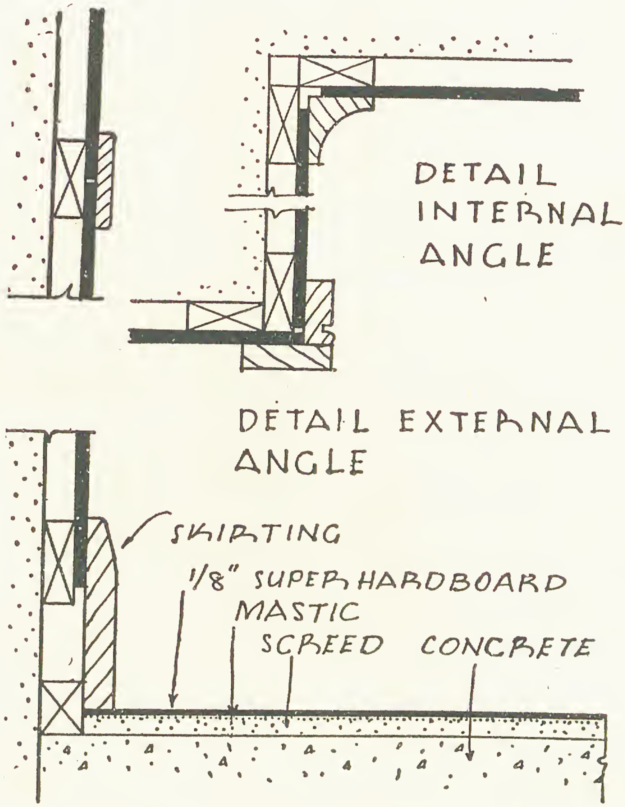


Fig. 185.—Details of wall-board fixing. Bottom detail shows hardboard used as flooring, bedded in mastic on cement screed.

Insulating boards can be decorated, and they are jointed by the methods used for all kinds of fibre building boards. Although of value in dealing with insulation problems, it should not be thought that $\frac{1}{2}$-inch insulating board will cure a case of noise penetration or completely prevent the passage of heat or cold. The value of the insulation should be calculated in relation to the particular case (see Chapter 5, Vol. IV) unless it is one of a familiar everyday kind.

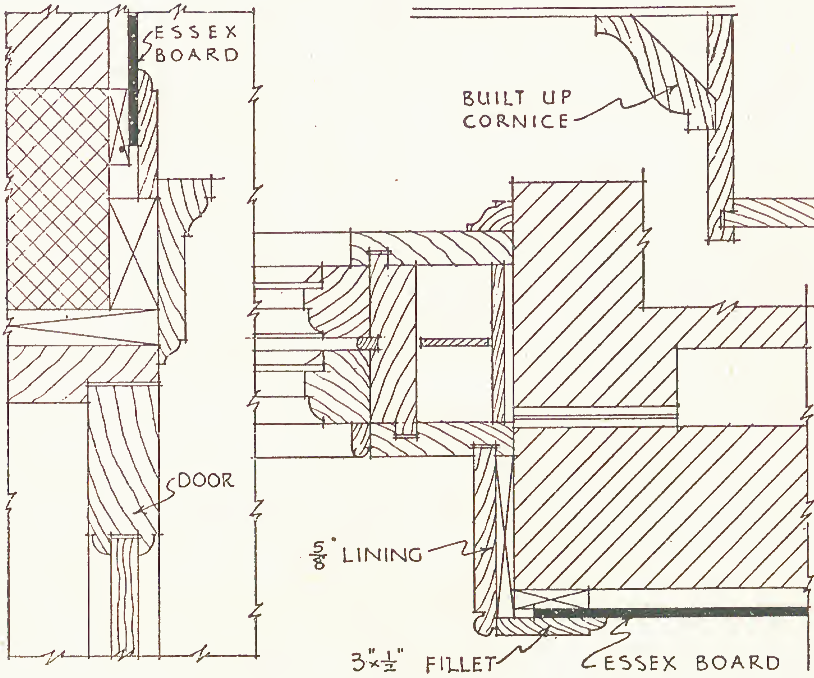
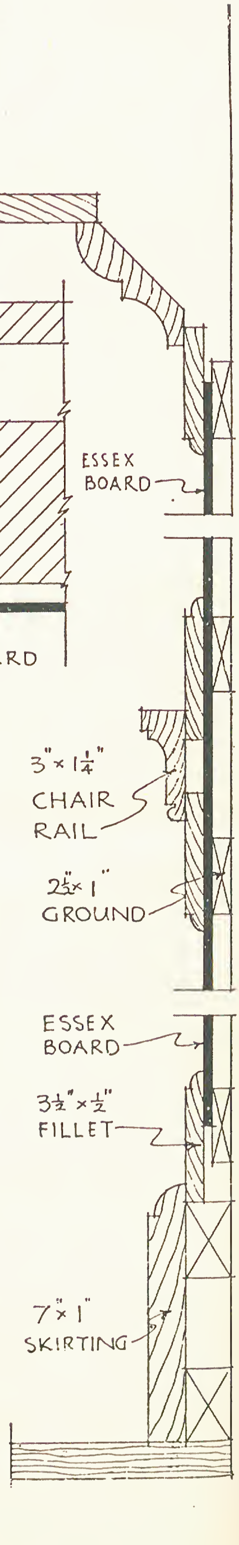


Fig. 186.—Details recommended for fixing Essex board.



2. ***Wallboards.***—These are boards for general use as wall and ceiling linings. They are of medium density and their insulation value is lower than Type 1 boards.

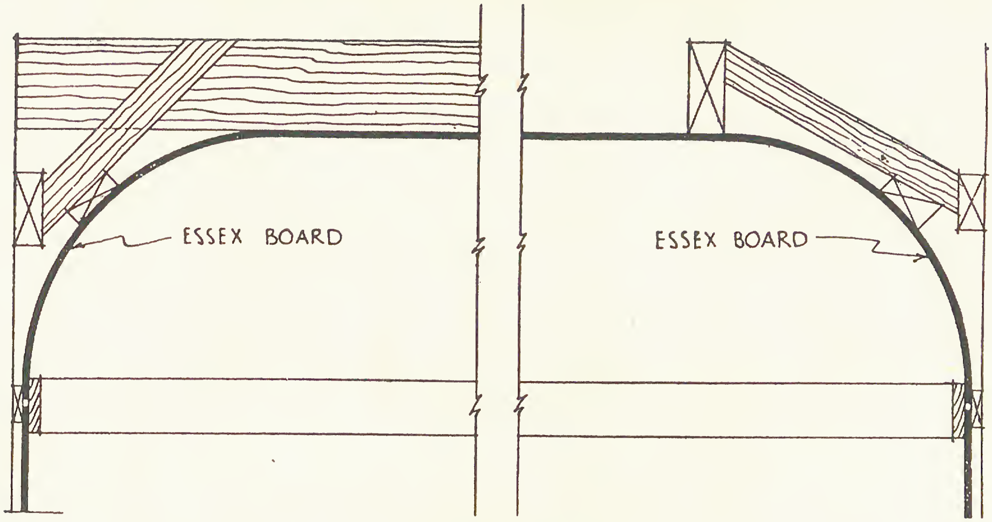
A homogeneous type is made in thicknesses of from $\frac{3}{16}$ inch to $\frac{3}{8}$ inch and a laminated type in thicknesses of $\frac{3}{16}$ inch to $\frac{1}{4}$ inch. A bitumen laminated type is made for use in damp situations.

Medium density fibre boards are widely used. Their strength is adequate for light usage but they should not be used where they may have to take heavy blows.

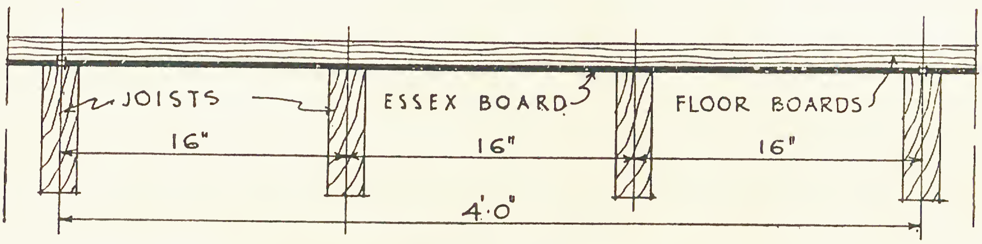
3. ***Hardboards.***—Although hardboards are fibre boards they are much stronger and denser than what is normally thought of as fibre board. They are compressed under great pressure which produces a dense tough material in some ways superior to natural whitewoods.

There are three types, according to the degree of compression or density: Medium, Standard, and Super.

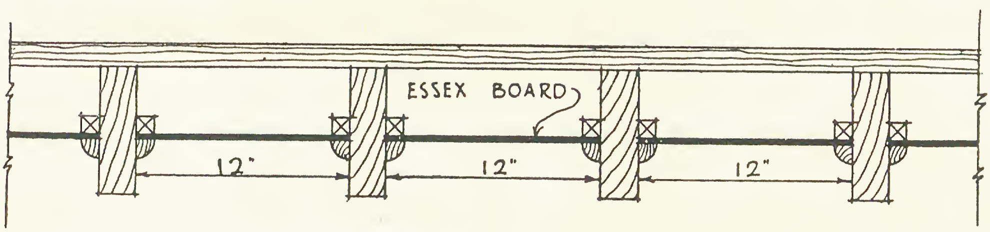
Hardboards have been used for many purposes, including such diverse uses as panelling and boat hulls.



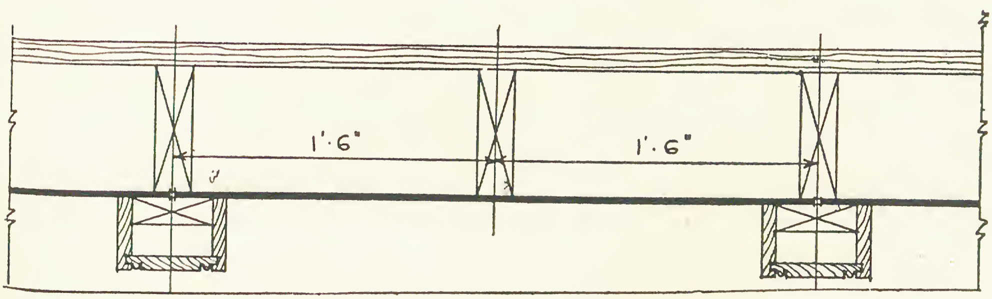
Coving.



The open ceiling.



The open ceiling panelled.



False beams over wall-board in place of plaster.

Fig. 187.—Methods advised in forming ceilings with Essex wall-board.

Advantages.—The following advantages are claimed for fibre building boards :

Large standardised sheets for speedy construction.
Easily handled, cut, and fixed without special equipment.
Facilitate " dry " construction.
Light in weight.
Suitable for either prefabrication or site fixing.
Eliminate cracked and falling plaster.
Easily adapted to any architectural design.
Flexible, may be used for straight or curved work.
Decorative finish.

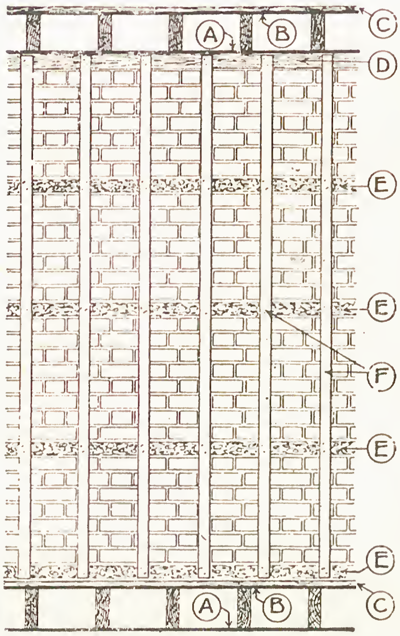


Fig. 188.—Methods advised for fixing " Sundeala " wall-board.

A = fixing to joists.
B = wall-board beneath floor boards.
C = floor boards.
D = end of battens fixed to wall plate.
E = battens nailed to breeze blocks.
F = cut nails recommended here.

Certain types of building board have additional advantages, such as provision of thermal insulation, sound control, base for plaster and cement rendering, hard-wearing surface, etc.

Fire Resistance.—Fibre boards are combustible, but recent investigations prove that they do not quickly take fire in normal building uses, and cases have been noticed where they have shown surprising ability to confine the fire in the early stages.

Special fire-resisting fibre boards are made which should be used where high fire resistance is desirable. Surface treatment of normal fibre boards after fixing can be used to increase the fire resistance. Ordinary distemper increases fire resistance to a useful extent. Fire-resisting paint can be used and is more effective than distemper. If a suitable type of fibre board is used the surface can be skimmed with gypsum plaster, which gives high fire-resistance.

Where proprietory steel angle and channel system of fixing are used, wood grounds and cover strips are not required, which reduces the fire risk.

Fixing Fibre Boards.—Fixing to walls, partitions, and ceilings in houses and other small buildings is usually done by nailing the fibre boards to wood battens, studs or joists. These supporting members should be spaced so that the edges of the sheet are supported and (for full width sheets) intermediate support is also provided.

The layout from the decorative standpoint is, of course, of great importance. A vertical panelled layout with wood cover strips used to be standard practice but in recent years new methods of making joints and

new ideas on decoration have produced more interesting and attractive layouts. One point against the older method of panelling with fibre board and wood strips is the effect it produces of a poor imitation of wood panelling.

It is better to use the material according to its own merits and qualities. A wide variety of joint treatments is now available and these have interesting decorative possibilities.

With open or butt joints, for covering with strip, the edges should not be tightly butted. A slight gap should be left to allow for normal shrinkage and expansion movements of the supporting structure without buckling the board.

The edges can be bevelled or bullnosed to produce a decorative line which does not need covering. Special steel planes are made for the edge treatment of fibre boards, though the bullnosed edge can be produced by sandpapering.

A mitre and V-joint is another decorative joint which does not need cover.

Another method of treatment is to introduce a fibre board strip a few inches wide between the sheets. The edges of both the boards and the strips are bevelled to form a V-joint and a third V can be cut down the middle of the strip. The strip can be treated in various ways—reeding is another.

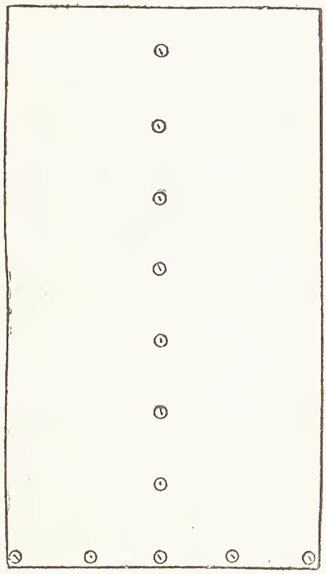


Fig. 189.—Method recommended for nailing "Sundeala" sheets. Nail in centre first.

If cover strips are preferred they need not be of wood. Fibre board

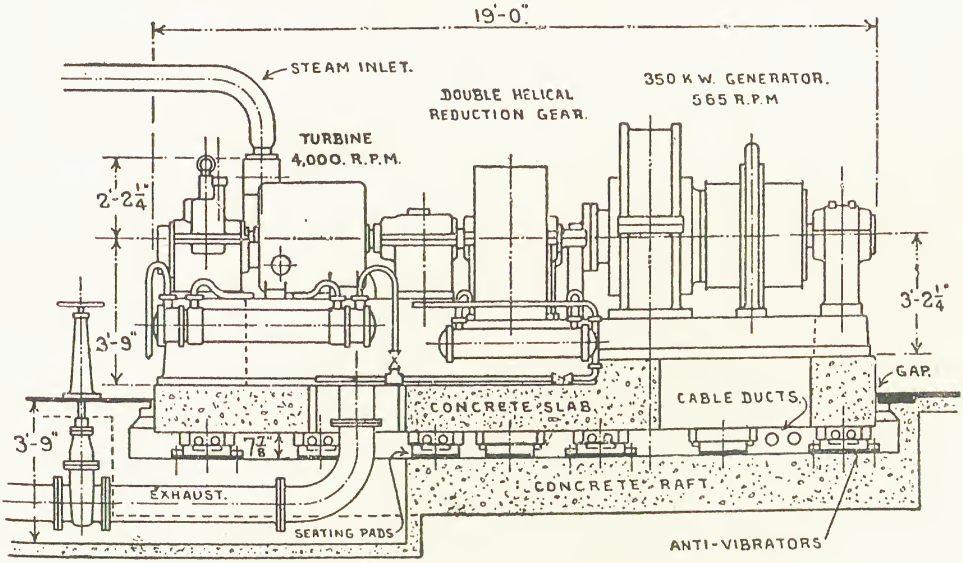


Fig. 190.—Soundproofing machinery within a building.

strips with bevelled edges can be used to cover the joints. Special aluminium alloy sections are made for use as cover strips, and some are of channel section to hold the edges of the boards.

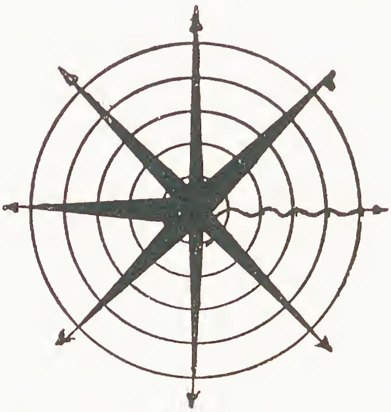


Fig. 191.—Noise expanding in every direction from a centre source.

Anaglypta cover strips of various sections are made. These are neater than wood strips and give an entirely different decorative line. Anaglypta strips are ductile and allow freedom of movement without distortion.

If wood is used for cover strips, thin hardwood strips with bevelled or bullnose edges are neater than thick softwood strips.

Sizes.—Most brands of fibre building board are made in lengths of 8 feet, 10 feet, and 12 feet. With some brands lengths up to 16 feet are made.

Standard widths are 3 feet and 4 feet.

Layout in relation to the size of the room and the standard lengths and widths of the sheet need careful consideration.

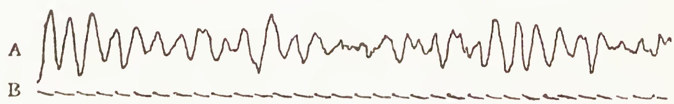


Fig. 192.—Sound vibrations.

It is usually possible to adopt a horizontal layout for small rooms which avoids vertical joints except at the corners. And two 4-foot sheets fixed horizontally cover the height of a normal 8-feet high room, though it is usually necessary to trim an inch or so off one board to obtain the necessary clearance. Two 3-foot boards plus a half-width board will also cover the height of an 8-foot high room, the odd 6 inches being covered by the skirting and the clearance gap between sheets. The half-width board can be obtained by cutting through a 3-foot board to make two half-widths, so nothing is wasted.

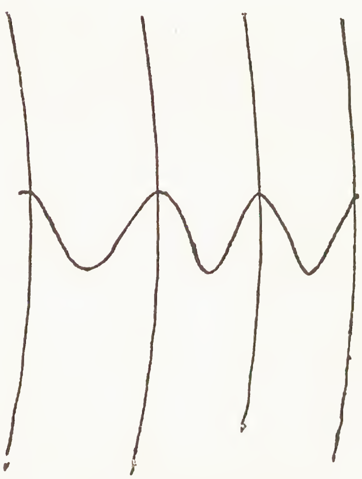


Fig. 193.—Sound waves.

With a vertical treatment, board lengths are available which will cover any height up to 14 feet without horizontal joints. If the standard widths do not cover the wall width without cutting it is advisable to have the corner sheets narrower than the others. A slight adjustment of the gap between sheets—if cover strips are used—may help in avoiding waste.

With vertical fixing, a frieze is a complication. If the frieze is 1 foot 6 inches deep it can be cut from standard 3-foot sheets without waste. But 1 foot 6 inches may be deeper than is required. It may then be better to adopt a 1-foot frieze, cutting it out of 4-foot sheets.

The skirting and picture rail give an opportunity to take a few inches from the wall area to be covered by the fibre board. In height this gives about 6 inches for adjustment.

A method of fixing which has not so far been mentioned, by lapping the edges of the sheets, also enables adjustment to be made to avoid cutting and waste.

Supports.—The maximum centres of supporting members (battens, studs, and joists) for most brands of fibre board is 18 inches for the 3-foot sheets and 16 inches for the 4-foot sheets. This gives support to the edges and intermediate support along the middle of the sheet.

For $\frac{5}{16}$-inch and $\frac{3}{8}$-inch homogeneous fibre boards support should be provided at 12-inch centres. All four edges of the sheet must be supported and in some cases intermediate cross support may be advisable.

The manufacturers instructions clearly state what support is necessary, and these should be carefully followed. Unfortunately these instructions do not always reach the hands of the men who fix the sheets. Sheets without adequate support tend to warp and bend, but if properly fixed they will remain flat and firm with normal fair use.

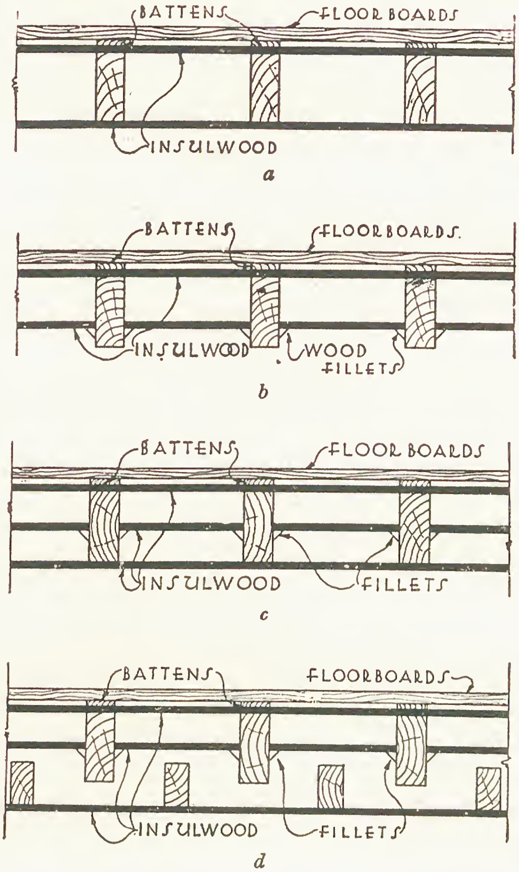


Fig. 194.—Floors insulated with "Insulwood."

(*a*) on both sides of joists.
(*b*) with open ceiling.
(*c*) (*d*) } methods of gaining additional insulation.

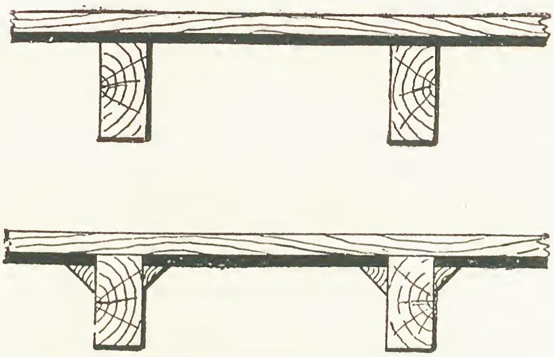


Fig. 195.—Wall-board on the "open" ceiling.

The supporting ground should be true. Battens should be plumbed on walls and packed out or scribed where necessary.

Wallpaper can be used over fibre board, carrying it over the joints, but whatever treatment is adopted for the joints there is always some risk of the paper splitting through slight shrinkage of the supporting ground. The joints should be treated by fixing strips of galvanised annealed wire mesh bedded on gypsum plaster, with the board margins slightly recessed by scraping or rubbing so that a flush joint can be made with plaster. Linen scrim is often used instead of wire mesh, but is not so reliable.

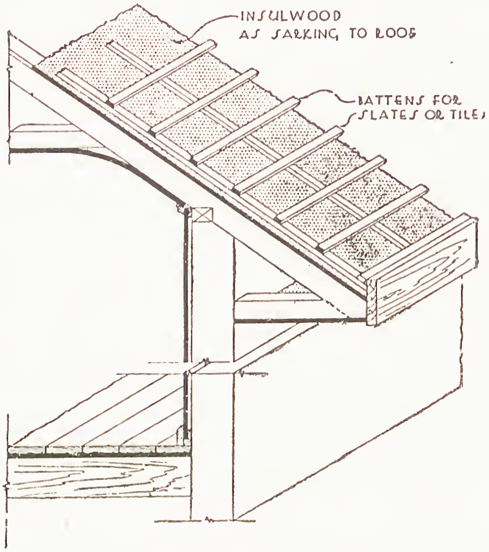


Fig. 196.—Method of insulating roof and floor with "Insulwood."

Where it is desired to plaster over fibre board, the $\frac{3}{8}$-inch homogeneous board should be used. The joints should first be given a priming coat of plaster and a strip of hessian or wire mesh should be bedded on this, securing it with galvanised tacks. But some makers supply a special plaster base fibre board and this joint treatment is not then necessary except at angles.

"Sisalkraft."—This product, though more in the nature of a building paper than wall-board, is useful for insulation purposes. It is composed of bituminous sisal fibres encased in sheets of tough waterproof paper; a section through this material being a top sheet of kraft paper, a layer of asphaltum, cross-sisal fibres, longitudinal sisal fibres, another layer of asphaltum, and a bottom sheet of kraft paper. It is supplied in rolls as follows:

36 inches wide containing	25	sq. yards
36 inches wide containing	$55\frac{1}{2}$	sq. yards
48 inches wide containing	133	sq. yards
60 inches wide containing	166	sq. yards
72 inches wide containing	200	sq. yards
84 inches wide containing	233	sq. yards

Plaster Boards.—Wall linings are made for use similarly to wall-boards, but of more fireproof material, the main component of which is gypsum. In some, the gypsum forms a core, being strongly sandwiched between fibre surfacings, and in others the gypsum is on the surface, forming an excellent fireproof substitute for lath and plaster. The last is made

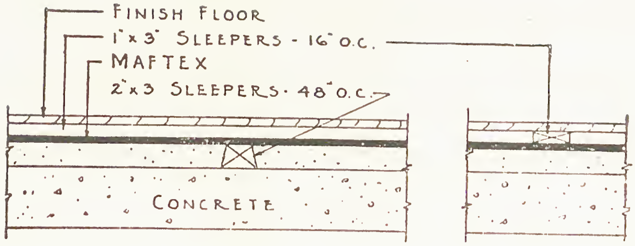


Fig. 197.—Sound deadening to concrete floor. Method advised with "Maftex."

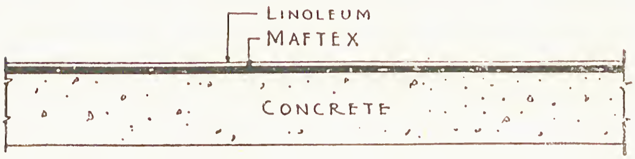


Fig. 198.—Wall-board under linoleum over concrete.

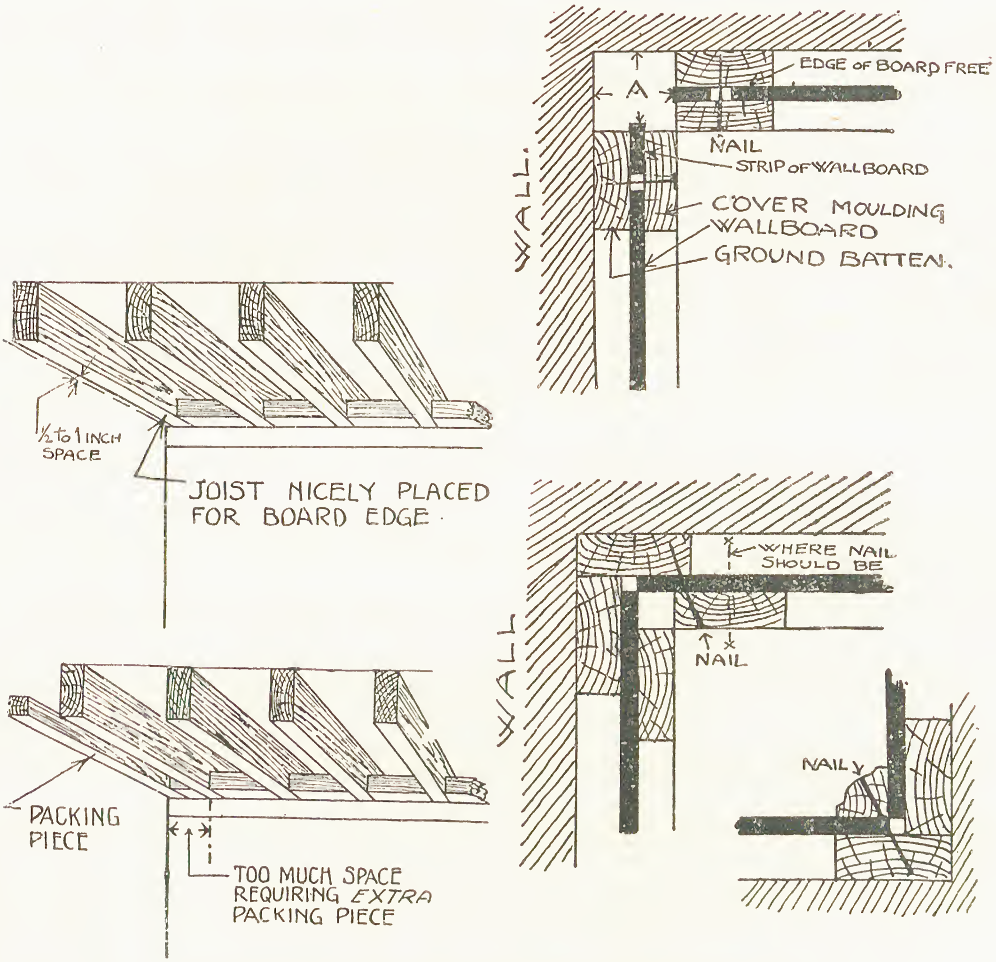


Fig. 199.—Details of fixing wall-board to ceilings and angles.

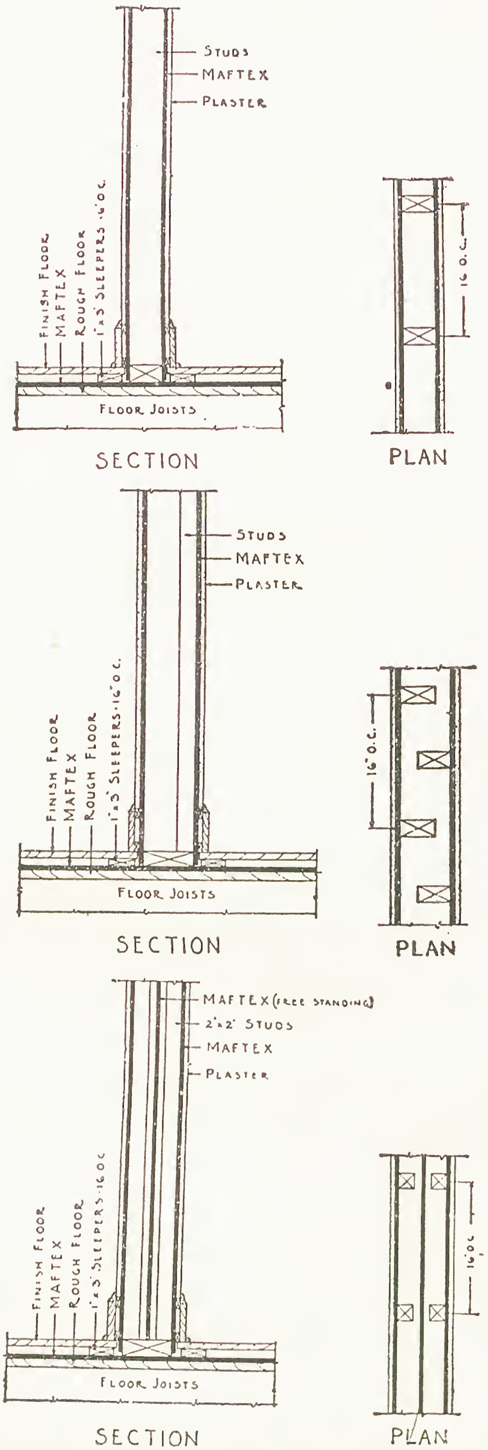


Fig. 200.—Soundproofing partitions with "Maftex" wall-board.

in sheets of $\frac{1}{4}$-inch and $\frac{3}{8}$-inch thickness, and in sizes varying from 12 × 4 feet, to 6 × 2 feet.

"Slagbestos" is a product of F. McNeil & Co., Ltd., used for the insulation of cold storages, also for insulation of heat and sound, and for sanitary use as a filter.

It is a pure mineral fibre manufactured from slag or a combination of rocks, by converting this in a molten condition, by means of a blast of steam or air, into a mass of exceedingly fine glass-like fibres, which interlace and cross each other. And in the operation of converting the raw material, the bulk is increased twelve times, so that the resulting fibres enclose eleven times their bulk in air.

"Plymax."—The subject of plywood will be found discussed in Joinery. "Plymax" is a plywood backed by metal, galvanised steel, aluminium, copper, and bronze being the metal used. It is supplied in three thicknesses; thin, approx. $\frac{3}{16}$ inch; medium, approx. $\frac{1}{4}$ inch; thick, approx. $\frac{3}{8}$ inch, $\frac{1}{2}$ inch, $\frac{5}{8}$ inch, $\frac{3}{4}$ inch.

Walls and Ceilings.—As well as for sheeting walls, "Plymax" has a variety of uses, including door panels, dados, decorative metal panelling, show-cases, table tops, etc., and can be obtained in Australian walnut, English walnut, Australian silky oak, English oak, Australian black beam, Indian greywood, and Burmah padouk, each in two grades, Venesta and Sylvan.

GLASS AS A WALL AND CEILING LINING

Glass is an excellent material for use as a decorative and easily cleaned

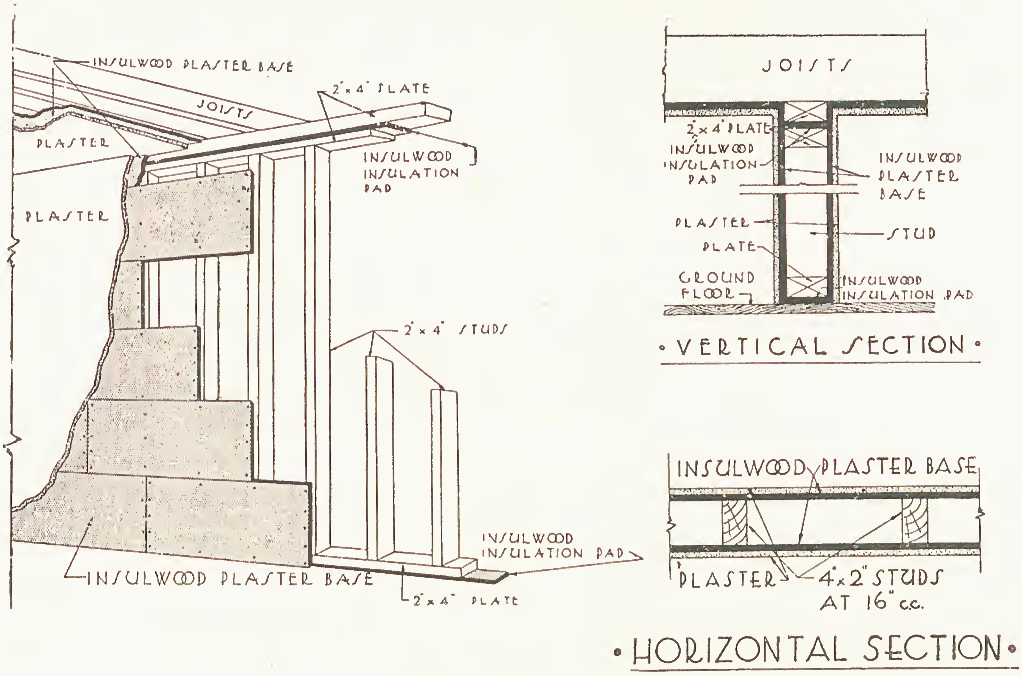


Fig. 201.—The "Insulwood" soundproofed partition with ordinary studding.

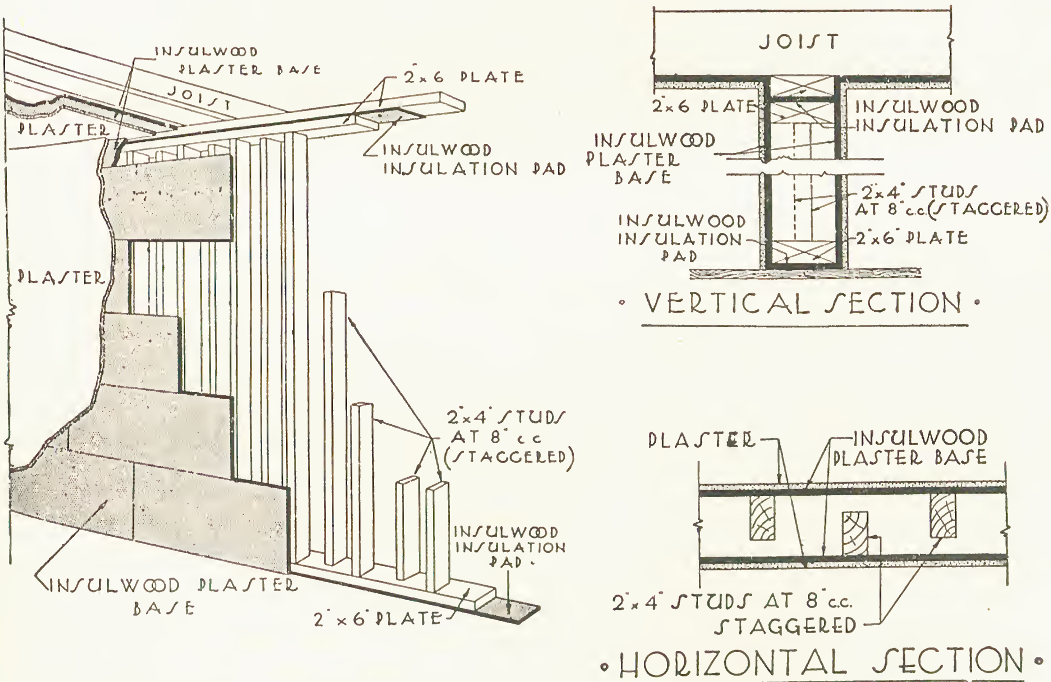


Fig. 202.—The "Insulwood" soundproofed partition with staggered studding.

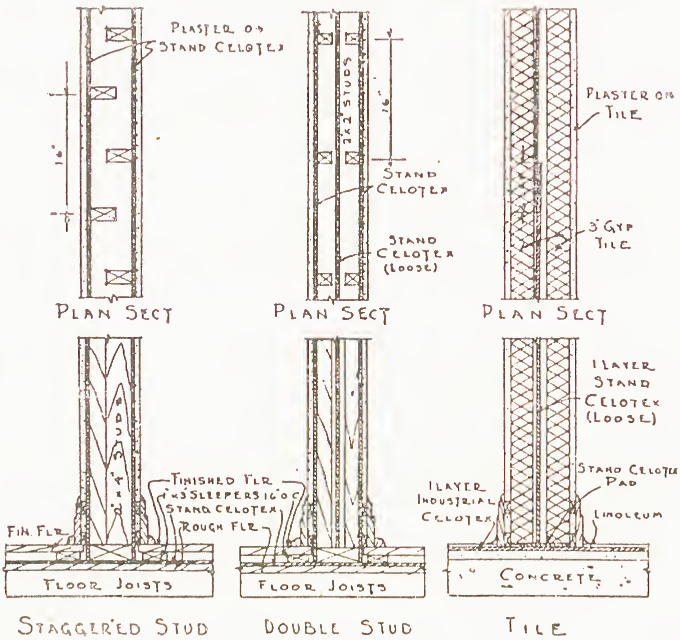


Fig. 203.—Soundproofing with wall-board.

wall and ceiling lining. The initial cost is rather high, but the material is so durable that re-decoration charges are nil. Although ordinary glass is rather easily broken, a special type (" Armoured " glass) can be used in positions where slight bumps have to be expected.

White, black, and coloured glass is made in two qualities :

1. Ground and polished surface, similar to plate glass. This is the most costly. It is chiefly used for bath panels, stall risers, architraves, and similar work of small area.
2. Fire-polished surface. Used for general wall and ceiling lining.

These glasses are marketed under proprietary trade names. In addition to black and white there is a wide range of colours. The usual thickness for ordinary interior work is $\frac{5}{16}$ inch, but ground and polished glass is made up to 1 inch thick, and the brilliant fire-polished glass up to 1 inch in black and white and $\frac{7}{16}$ inch in colours.

The standard " ashlar " sizes are : 12 × 8 inches, 15 × 10 inches, 15 × 15 inches, 18 × 12 inches, 21 × 14 inches, with big panels up to 60 × 36 inches.

Method of Fixing.—The most usual method of fixing opaque glass is that known as (1) *Adhesive Fixing*. In this a special mastic is employed, the chief constituents of which are white lead, gold size, linseed oil, putty, and certain other ingredients, which help towards quick drying and maximum adhesion. It may be applied to cement-rendered walls, breeze partition slabs, plaster, and painted walls.

Where the walls are damp they should be treated with a damp-preventive first, and unpainted wood is not advised, as it absorbs the gold size too readily before the mastic has set. The mastic should be spread evenly over the whole back surface of the glass, and the result of this is that the glass is no more liable to breakage than any other material. The edges of the glass panels are ground flat to butt accurately one to another.

(2) *Screw Fixing* is an alternative method, generally used for bath

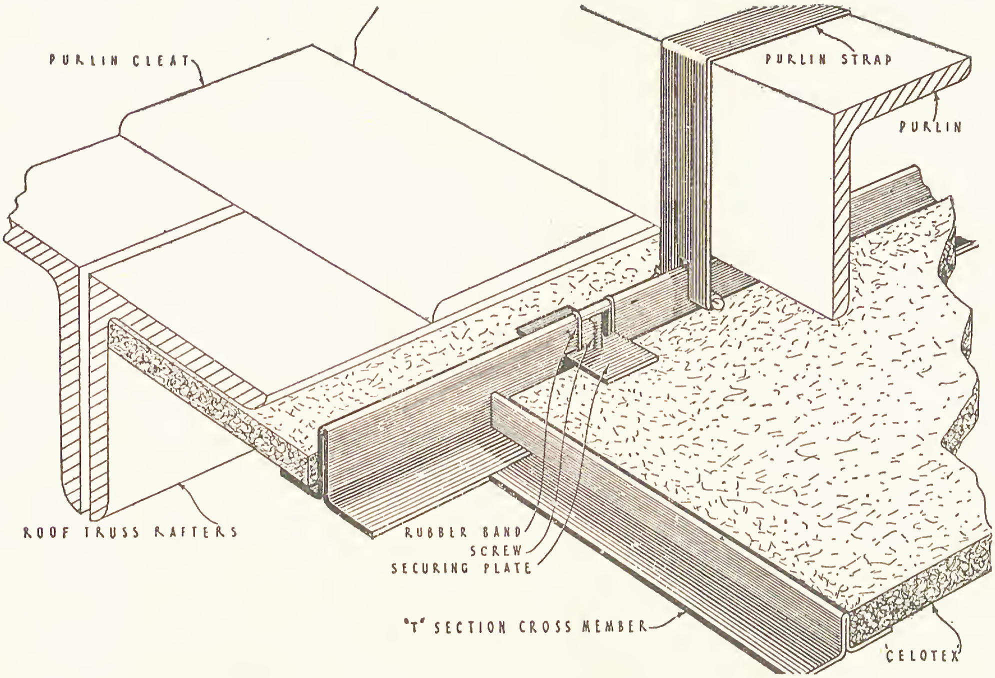
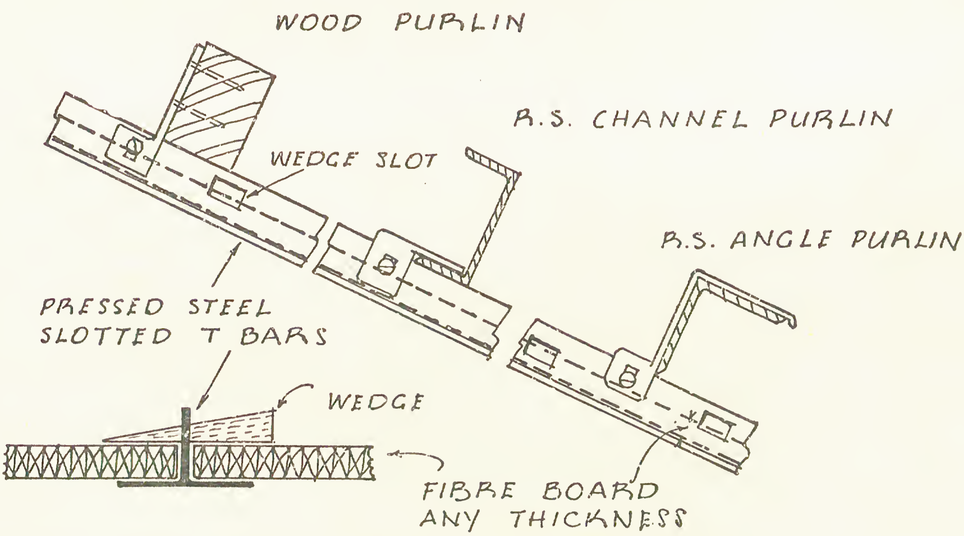


Fig. 204.—Celotex system of metal fixing, based on T and L sections in conjunction with small metal securing units. Suitable for most types of buildings for ceilings, walls, and partitions, and particularly for lining existing framed buildings.



BAR AND WEDGE FIXING TO PURLINS

Fig. 205.—A patent method of fixing fibre board to ceilings and walls. The sheets are secured to sheradised pressed-steel slotted T bars with wedges. (*Courtesy of F. C. Anderson & Sons, Ltd.*)

panels, splash back where access is required to pipes, and for covering doors with glass, and similar work. In this method the panels are drilled to receive screws, and the edges are treated as in the former method. The screws may have detachable heads of bright metal, bronze or glass, or the holes may be counter-sunk, and the screw tops covered with wax of a similar tint to the surrounding glass.

(3) *Fillet Fixing* is a third method, recommended when the whole of the wall is not to be covered, and the glass is to form a dado only. The panels are fixed by means of beads, top and bottom, the joints being covered by T fillets.

" Staybrite " steel, or similar metal, is often used decoratively in this way when it is preferable to use mastic as an additional safeguard against breakage.

Beads of either wood or metal are invariably used for ceiling work with 21-oz. opal sheet, the size of the sheets of glass being anything up to 24 × 24 inches. The back of each sheet is treated with a canvas backing for safety in case of breakage.

An example of glass used as an external wall sheeting is to be seen in the *Daily Express* new offices in Fleet Street, London, which were completely faced with black " Armourplate " glass. This sheeting covers a concrete building, the sheets of black glass 8 × 6 feet being secured to the concrete by $1\frac{7}{8} \times \frac{1}{4}$-inch bars attached to lugs grouted into the concrete, and a pumice concrete filling is laid in between the back of the glass and the concrete.

Over the flat bars are $2\frac{1}{4}$-inch " Birmabright " strips, which cover the joints.

TILING

Wall tiling is used for dados in sculleries, bathrooms, and in the most modern kitchens entire walls are covered with tiles.

Wall tiling is also extensively used in hospitals, and in similar conditions where hygienic conditions are of first importance.

To fix the tiling a backing of cement mortar, in the proportions of 1 part Portland cement and 2 parts sharp sand, is required. This should be made, screeded level, and covered with a $\frac{1}{2}$-inch layer of neat cement; the tiles before use should be thoroughly soaked in water and for fixing their edges should be dipped in a grout of Keene's or Parian cement, and pressed into the layer of cement. Each tile is brought into position and pressed tightly down against the neighbouring tiles, the joint being formed as thinly as possible. The surplus cement which oozes from the joint should be wiped away.

An alternative method of laying tiles on walls is to attach to the wall a framework of studding, over which expanded metal lathing is fixed. This serves to form a key for the mortar, which, to give it extra strength, should have a small addition of hair. This method is used mainly in repair work over rough walls of old buildings. Where large and especially

high surfaces have to be covered with tiles, it is helpful if the surface is broken up into panels, framing these with flat tiles coloured or enamelled on the edge. These form a bond by being tailed into the mortar behind the cement.

For the tops of dados special moulded flat tiles are to be obtained.

Marble Tiling.—Outside surfacing of walls, mainly for shop fronts, is executed in marble tiles from sawn slabs. These should be laid on a flat surface of Portland cement, perfectly bedded solid, and as with the glazed tiles, the fixing is made more secure if held in position with either flat tiles or special metal strips, such as " Birmabright."

Marble has, in the more modern work, given way to the newer materials described above for exterior wall facings, and this is no doubt mainly due to the fact that marbles are very slightly soluble in pure water, and even more so where the water contains carbon dioxide or sulphuric acid, as it does frequently in city atmospheres.

CHAPTER 14

BUILDING DEFECTS AND REPAIRS

DEFECTS in buildings may be considered under the following heads :

1. *Decay.*—The disintegration of materials (by chemical decay usually assisted by the action of the weather), and including the decay of timber by dry-rot fungi and insect attack.

2. *Dampness.* By this is meant the admission of dampness to the inside of the building to the detriment of the materials, the furniture, and the occupants. Dampness may be the result (*a*) of faulty design or workmanship, (*b*) decay of materials, or (*c*) structural failure.

3. *Structural Failure.*—This may be due to faulty design or workmanship, or may follow on decay or dampness.

It is important to recognise the fundamental causes of the defects so that appropriate measures can be taken to cure them. A lot of money is wasted on repairs which cover rather than cure defects.

Weather Effects.—The action of the weather on building materials should be understood so that they can be properly protected.

Many building materials are absorbent, especially the traditional wallings, brick, stone, and mortar. Concrete, clay tiles, ordinary cement renderings, roughcast, plaster, and wood also absorb water to a greater or lesser degree. These materials must either be protected from rainwater or used in such thicknesses that prolonged rainfall does not result in absorption of water from the outside to the inside.

The non-absorbent materials are used for the most exposed parts of a building and to give protection against damp to the absorbent materials. Thus slate is used on low-pitched roofs, asphalt and bituminous felt on flat roofs, slates, asphalt, lead, and copper for damp-proof courses and flashings, to give a few familiar examples.

Damp-proof Courses.—The wall surfaces exposed to the atmosphere quickly dry-out after rain, but rainwater is stored in the ground, which may remain damp around the foundations for long periods. It is essential to prevent this ground damp rising up the walls, and for this purpose certain impervious materials are used in horizontal courses placed about 6 inches above the ground and below the ground floor, as described in Vol. II, Chapter 1.

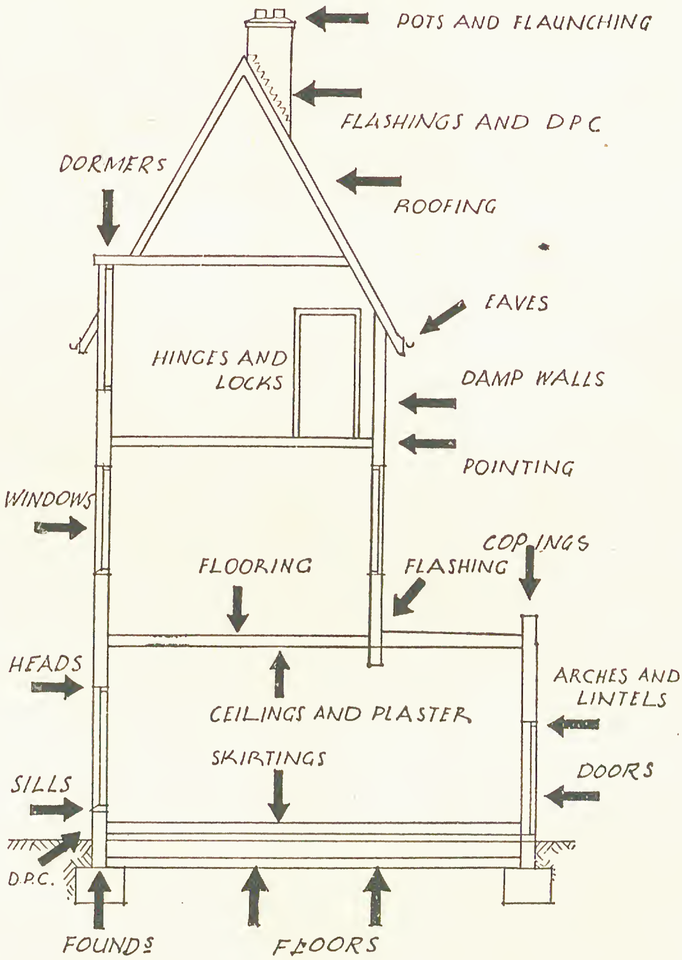
Rainwater will soak down a wall from a chimney-top or parapet much quicker than it will soak through a wall from the outside vertical surface. Damp-proof courses are therefore necessary in chimneys and under the copings of parapet walls.

Where floors are below ground-level, as in basements, vertical damp-proof courses are built into or on the surface of exterior walls to prevent damp from the ground passing through the walls.

It is also necessary to prevent damp rising from the ground through the ground floors. Under wood joist and board floors a layer of cement concrete is usually spread, and the space under the wood floor is ventilated by building air bricks into the outside walls just above ground-level and leaving gaps (" honey combing") in the sleeper walls which support the floor joists at intermediate positions.

The surface concrete under solid floors serves the double purpose of sealing off the flooring from damp and supporting the flooring.

Surface concrete, however, is not absolutely waterproof. It may be satisfactory on a site such as sandy gravel which provides good natural drainage, or when used as oversite concrete under a well-ventilated wood floor, but on a clay site, a basement floor, or when used to support rubber or composition flooring, trouble may be caused by damp rising through the concrete.



VULNERABLE POINTS IN A MODERN BUILDING

Fig. 206

In such cases it is advisable to lay a damp-proof course right through or on the surface concrete, and this should be turned up the wall and connected with the horizontal damp-proof courses to form a waterproof " tank."

DAMP WALLS AND FLOORS

With the foregoing in mind we may look for the causes of damp walls and floors in :

A. Absence of or faults in damp-proof courses.

B. Decayed or excessively absorbent walling.

In both cases, external conditions may aggravate the trouble. If the site is a clay basin the ground may become waterlogged in wet weather and any weakness in the damp-proof courses will admit damp.

If the mortar joints of the walling are in bad condition, or if the bricks or stones have decayed or are excessively porous, damp will be readily admitted on a wall exposed to rain-bearing winds (usually on the south and west sides).

Inserting a New Damp-proof Course.—If there is no damp-proof course the walling material must be cut away in short lengths and a damp-proof course consisting of two courses slates in strong cement mortar inserted, the slates lapping to break joint. This can usually be done in lengths of 18 inches, though it depends on the strength of the walling.

A damp-proof course must be at least 6 inches above ground-level so that rain striking the ground does not splash up and soak the wall above the damp-proof course.

A common cause of damp walls is found in a damp-proof course an inch or two above ground-level, and in some cases the earth is piled up when digging the garden so that it covers the damp-proof course. In both cases, the remedy is to lower the level of the earth.

Damp Basements.—In the case of a basement, or where the " ground " floor is a few feet below ground-level, dampness in the walls calls for a new vertical damp-proof course. This can be provided inside or outside.

Asphalt can be used on the outside, the soil being excavated and the wall prepared by deeply raking the joints to form a key. Asphalting must be done by experienced workmen, and there are many firms specialising in this work.

A waterproofed Portland cement rendering, applied either to the inside or outside of the wall, makes a good vertical damp-proof course. There are several reliable proprietary waterproofing compounds. These should be used strictly to the maker's instructions. The wall face must be prepared by cleaning down the face and raking the joints.

If the ground is waterlogged the pressure of water against a basement wall may be considerable, and it is therefore advisable to have the vertical damp-proof course on the outside. Placed inside, it might be forced off the wall.

In all cases the vertical damp-proof course should be brought up from foundation-level to the horizontal damp-proof course above ground-level.

Damp Floors.—In a wood ground floor, if dry rot has been discovered the first thing to suspect is the under-floor ventilation, about which more

will be said later. If this ventilation is satisfactory, it follows that dampness is the cause. Examine the horizontal damp-proof course. It may be defective, or it may be above the floor joists.

In waterlogged ground the dampness may rise from the ground under the floor. In old buildings there is no over-site concrete, and even in some fairly modern buildings there is only a covering of lime riddlings. If it is established that the ground under the floor is damp, the floor must be taken up and a bed of cement concrete laid on the ground. If the ground is firm, a 4-inch thickness is sufficient, but it is advisable to lay it in two thicknesses, the top $1\frac{1}{2}$ inches being waterproofed with a suitable compound. Alternatively, the top of the concrete may be treated with silicate of soda (waterglass) of the brand known as P.84. This is applied after the concrete has set, and it seals the surface pores.

If dampness rises through a solid floor laid on the ground, the flooring should be removed, the old concrete surface hacked and a thickness of $1\frac{1}{2}$ inches waterproofed cement-sand mix floated over. The new tiles, composition, or other flooring can then be laid.

Old stone-flag floors should be taken up and a solid floor with a 6-inch thick concrete base should be laid.

Treatment of Damp Walls.—Correct diagnosis is the first essential. Moisture can travel some distance through the interior of a wall before it appears inside. If the damp-proof course near the ground is sound, the dampness may penetrate in one of the following ways:

Directly through the wall.

Through gaps between window and door frames and wall jambs and heads, or under sills.

Downwards from exposed parapets and copings.

Downwards from leaky roofs.

In the case of direct penetration, this may be due to the wall being exposed to rain-bearing gales. Even the best-quality solid brickwork in strong mortar may admit damp in this way. In old buildings the penetration may be due to decay of the walling, or possibly of the mortar joints only.

In the latter case re-pointing with fairly strong mortar should cure the trouble. But it is a mistake to use a strong cement mortar. Such a mortar shrinks and opens fine cracks and fissures. A cement-lime mortar is best.

If the walling is defective, cut out any old bricks or stones and replace with new.

Rendering.—This is a good treatment for both old and new walls which are damp. It is just possible that ordinary cement-sand rendering, either floated or roughcast, will cure the trouble. But such a rendering is not waterproof—it merely provides an extra thickness of material, and so delays the penetration of moisture to the inside. To make the rendering waterproof a good proprietary waterproofer should be added to the rendering mix.

If it is not desired to cover the outside of a good-looking brick or stone wall with rendering, the treatment may be applied to the inside surface. In this case the plaster must be stripped, and the rendering must be carried some distance along partition walls joining outside walls If an interior rendering is waterproofed there is some risk of condensation owing to its impervious nature.

Renderings must be carried into reveals or jambs.

Tile Hanging.—Covering the outer surface with tiles or slates is a good method of waterproofing, though rather costly. Plain tiles are used with special corner tiles at corners and reveals. This method is suitable for rather large wall surfaces, but window and door openings rather close together complicate the work.

In most cases $1\frac{1}{2}$ inches is sufficient lap, which with $10\frac{1}{2} \times 6\frac{1}{2}$-inch tiles gives a gauge for the battens of $4\frac{1}{2}$ inches. The horizontal battens may be nailed to plugs in the wall, but it is better to fix vertical battens first, using fibre plugs and rustless screws. The horizontal battens can then be easily nailed in position after marking the gauge on the vertical battens.

Every tile should be nailed with two $1\frac{3}{4}$-inch copper or composition nails. The tile nibs transfer some of the weight to the battens, but on vertical work each tile must be nailed to avoid slipping.

This is an excellent treatment also for timber or boarded walls.

Tile hanging is illustrated in Vol. II, Chapter 1.

Copings.—Water may soak down walling material from defective copings and chimney-heads. Even if the coping is sound it may absorb water. In case of dampness from this cause, remove the coping and place a horizontal damp-proof course in the parapet wall just above roof-level, preferably to make contact with the gutter flashing.

Chimneys should have a damp-proof course just above roof-level.

Copings and chimney-tops should be weathered and projected so that water runs off, and the materials used should be hard and dense. Pre-cast concrete is perhaps the best material for this purpose.

String Courses and Cornices.—As these project they catch the rain-water running down the wall face. If there are any cracks or defects the water soaks into the wall. String courses are sometimes finished with a weathering of cement mortar, but this is liable to crack. A lead flashing is better. This should be turned up the wall and tucked into a bed joint, afterwards neatly pointing the joint.

Stone cornices may be badly decayed. They may be cut off to a vertical surface 1 inch back from the wall face, the depression being rendered in cement mortar (preferably white or buff-coloured cement), or re-made by first covering with expanded metal lathing secured to fibre or white-metal plugs, and then working up a new moulding in cement-sand mix. The weathered top must be protected with lead, copper, or zinc.

Pointing Frames.—Damp is often admitted between door or window frames and wall jambs. It is not enough to cover the gap with a small moulding, or to point it with mortar. A mastic pointing should be used. There are several proprietary brands on the market which retain a certain elasticity, enabling them to maintain close contact with both frame and jamb in spite of shrinkage in the frame. After pointing, a small scotia or other moulding should be nailed over the joint.

Sills.—Like cornices, sills catch a lot of water which will penetrate any cracks and soak through excessively porous material.

Defective wood sills can be covered with lead or copper, close copper nailing the lower edge to the face of the sill and tucking the upper edge into a groove.

Decayed stone sills should either be removed and replaced with pre-cast concrete sills, or hacked and rendered with a cement-sand mix.

Water often penetrates the gap between the wood sill and the brick, stone, or other sill. This should be pointed with mastic material tamped well into the gap. In new work a lead flashing turned up into a groove under the wood sill is often adopted.

Water may penetrate window heads. If this cannot be cured by pointing round the frame with mastic material, a window hood or projecting wood moulding may be fixed to wall plugs and then covered with lead or zinc, tucking the upper edge into a bed joint.

Care should be taken that all projections, cornices, hoods, mouldings, etc., are weathered and have some form of drip edge to throw the water clear of the wall.

Cavity Walls.—Properly constructed, these walls should be waterproof. Faults are common. They are described in Chapter I, Vol. II. Unfortunately they are not easily remedied. If a cavity wall admits water all over, a remedy such as rendering or tile-hanging must be resorted to.

Waterproofing Liquids.—The application of a proprietary liquid waterproofer is the cheapest treatment for a damp wall (if the trouble is due to direct penetration). Although these liquids are colourless they give a slight "glaze" to the surface and also darken the tone a shade. They are not permanent and need renewal at intervals of from three to five years.

ROOFING

The defects met with in roof coverings range from one or two tiles or slates which have slipped, a defective flashing, or a choked gutter, to general decay of tiles or the breaking-up of the whole roof due to decay of the rafters and battens.

Slipped Tiles and Slates.—This is a common defect. On most tiled roofs only one course in four or five is nailed. If an unnailed tile has a twist or defective nibs it may slip down. It can easily be pushed back, but the trouble is likely to recur, so the best thing to do is to take the tile out

and insert a sound one. To do this lift the edges of the surrounding tiles slightly and insert wedges while the new tile is slipped into place. Take care that the nibs " hook " over the batten.

Slates slip through the nails corroding. Sometimes only one nail breaks and the slate swings. To cut the remaining nail a special tool called a ripper, with a small hooked blade at the end, is inserted under the slate. The blade is then hooked round the nail and by giving a sharp pull the nail is cut and the slate can be removed.

As slates are fixed by nailing, and the batten is not accessible, to replace the slate or fix a new one it is necessary to use a copper clip. This is a strip of metal about $1\frac{1}{2}$ inches wide and long enough to project beyond the tail of the slate so that it can be turned up to hold the slate and prevent it slipping. The head of the clip is nailed to the batten through the narrow gap between the slates underneath.

An old slated or tiled roof may be very leaky through the general decay of the rafters and battens. The roof sags and opens gaps between the slates or tiles.

Surface Treatment of Slates and Tiles.—A cheap method of treating such a roof is to point the gaps with cement mortar, but it is unsightly and the mortar will crack as further settlement occurs.

Several mastic and liquid materials are on the market which are of a bituminous nature. They can be used to waterproof any leaky roof, pitched or flat. There is a red colour for use on tiled roofs. These mastic " paints " retain elasticity, and so do not crack if further movement of the roof occurs, but they are unsightly on a pitched roof.

If the roof is in bad condition the only satisfactory thing to do is to strip the tiles or slates. The condition of the battens and rafters can then be seen. If the rafters are sound, a little strengthening with ties and struts will prevent further settlement, and new battens can then be laid and the roof covering re-fixed.

In treating old roofs it may at first appear that only a few tiles or slates have to be attended to, but on attempting this other tiles or slates may slip and so the defects may spread until the whole roof is involved.

Defective Flashings.—For cheapness, a bituminous mastic can be brushed over a defective flashing to close the cracks. But it is more satisfactory to remove and replace with new lead or zinc.

It may be that the existing flashing is defective in design or placing rather than in material. This point should be borne in mind, as it is useless to cut the new flashing on the pattern of the old if it is unsuitable.

Flat Roofs.—Here again a bituminous mastic can be used for pointing cracks, and a bituminous liquid for all-over treatment. This is a good remedy for numerous slight defects.

Asphalt is very easily repaired, but the work should be entrusted to a specialist contractor.

Lead, zinc, and copper roofing may develop defects through damage to

seams and rolls by treading on them. Small cracks can be stopped by soldering, but leaky rolls and welts should not be soldered for any great length or the freedom of the metal to expand and contract will be interfered with.

Extensive defects cannot be efficiently repaired, and it is better to strip the roof and relay with new material.

DEFECTIVE WOODWORK

Under this heading we may consider dry rot, insects in timber, faulty design, and structural defects in framed woodwork.

Dry Rot.—This is caused by fungi which feed on the timber. The conditions under which a fungus may grow on timber are dampness and poor ventilation. Darkness also favours growth.

The space under ground floors should be ventilated as described in Vol. III, Chapter 3. The vents must be placed so that a through current of air can ventilate the whole of the joists and underside of boards. If a solid floor intervenes, glazed stoneware pipes should be laid under it communicating with air bricks so that a through air current is assured. It is useless to place air bricks on one outside wall only.

In treating a case of dry rot, drastic measures must be adopted. All infected timber should be taken out and burnt. The brickwork and surface concrete should be sterilised by passing the flame of a blow-lamp over it, so that any fungus spores are burnt. New timber should be treated with preservative for a foot or two at the ends and bearings.

It is difficult to properly ventilate joist ends built into walls. A pocket should be left in the wall so that the only part of the joist in contact with the wall is the bearing on the underside and for this reason the joist end should be soaked in preservative. The faces of the pocket should also be brushed with preservative to kill any remaining spores.

The new timber should not be fixed until the conditions which caused the dry rot have been remedied. If damp is rising through the surface concrete, float a 1-inch rendering of waterproofed cement-sand over it. If ventilation is unsatisfactory put this right by adding extra air bricks, cutting holes in sleeper and partition walls, or doing whatever is necessary to ensure *through* ventilation.

Dry rot in upper floors, partitions, and roofs is rare and is due either to the use of infected timber or to dampness. Thorough sterilisation of surrounding brickwork is essential, either by treating with an odourless preservative or by using the blow-lamp. It is advisable to replace rotten partitions with plaster or breeze slabs.

No attempt should be made to treat infected timber with preservative. It must be removed and burnt.

Outside Timber.—An enormous amount of fencing and other outside timber is destroyed every year by rot. This starts very quickly at the

point where posts enter the ground. Ordinary brush treatment with preservative will only protect timber for about twelve months. All fencing posts should be treated in heated creosote for forty-eight hours, or, better still, pressure treated. In repair work, where proper plant for such treatments are not available, it is advisable to char the stumps over a fire. This gives protection for many years. Alternatively, the old posts should be replaced with pre-cast concrete posts.

Insects in Timber.—Insects weaken timber by boring through it. Theoretically the progress of the trouble can be stopped by soaking the timber in preservative or certain chemicals, but the difficulty is in doing this. Brush treatment is useless unless it is frequently repeated over a number of years. The treatment then kills any eggs laid in crevices. It is better to remove and burn badly infected timber and to replace with new material treated with preservative.

Doors and Frames.—Any rotten woodwork should be cut out and replaced with new. Frames may rot at the feet. A new length should be joined with a halved joint, but as it is impossible to dowel the new foot to the step, it should be secured by screwing to wall plugs inserted in a brickwork joint from the inside. Loose frames can be secured by the same means.

Split panels can be covered with new thin panels nailed on. The back of the new panel should be lead painted and fixed before the paint dries.

Loose mortised joints in doors can sometimes be put right by laying the door flat and placing it in two or three joiner's cramps. The joints can then be pegged and the wedges tightened. If all the joints are loose they should be taken apart and re-glued and cramped.

In exposed positions outside doors may admit water. A weather moulding may be added to the bottom rail to prevent water being blown under the door. The best form is a thick 6-inch board with one edge bevelled so that it can be screwed to the door. A triangular block should be fixed at each end to strengthen it. A rustless metal weather bar should be fixed in cement in a groove in the step to keep water and draught out.

The linings of interior door jambs are often so thin that there is insufficient thickness of wood in the rebate to hold the hinge screws and the hinges become loose. The linings should be removed and pieces of wood fixed at the back of the hinge positions to give the necessary thickness of material.

It does not pay to put much work into the repair of ordinary deal doors and linings as new ones can be bought at low cost.

Windows.—Casements which swell and will not close, or which admit water, are all too common. Unfortunately, when the edges are planed to allow the casements to close into the frame rebates they are seldom painted, with the result that moisture is again absorbed and the casement continues to swell. This process is in time followed by loosening of the

joints. If a casement is in bad condition it is better and often cheaper to fit a new one.

Loose joints may be remedied by cramping and pegging, as already described for doors.

Leakage between frame and walling may be cured by pointing with a suitable mastic. As already explained, mortar is not suitable for this purpose. Nail a small moulding over the mastic. This will prevent evaporation of the oils in it and make a neat finish.

Staircases.—Slight defects result in creaking. The staircase should be strengthened by screwing blocks between treads and risers, and if there is any marked sagging two timber carriage pieces should be added underneath to which triangular pieces 1-inch thick should be screwed so that new support is given to the whole staircase.

Loose newel posts may sometimes be secured by putting a screw or two in the right place, and loose balusters and handrails by skew-nailing. An open staircase sometimes settles owing to insufficient support. It may be restored by jacking up from a stout shore and a post can then be fixed to make a tight fit between floor and string or landing joist.

Floor Boards.—Shrinkage in the width, opening the joints, is a common defect. The gap, if wide, should be filled with wood slips glued in, and a water-resistant glue should be used. Slight gaps may be filled by working in plastic wood, but this is liable to shrink slightly.

The gap between the bottom of a skirting and the floor may be filled with a small scotia moulding pinned to the floor only.

Fixings.—Loose fixings are common in old buildings. The old-type fixing consists of a wood plug or block to which the fitting is screwed or nailed. The wood shrinks or rots in time. The modern fibre or white-metal plug for light fixings is very much better, and for heavy fixings a patent expanding bolt should be used.

In addition to the above, many defects are described throughout these four volumes. Two important principles of repairing may be mentioned : to discover the cause before deciding method of repairing ; and to make a *thorough* repair job. Many building repairs are unsatisfactory owing to neglect of these principles.